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BRITISH LOCOMOTIVES IN 1928.

DESIGNS AND WORK.

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Figs. 1 to 8, pp. 216 to 221.

I. — Designs.

During the year there were a number of additions to the new and notable locomotive designs of 1926 and 1927, so that engines which in those years constituted distinctive novelties have during 1928 become the class engines for substantial numbers of others built to the same drawings and sufficiently numerous to have become the standard engines for certain train services. The year has also to its credit several interesting new designs and some notable rebuilding operations with engines introduced a number of years ago. During the year there were some important developments in long non-stop runs, including the provision of corridor tenders to enable enginemen to be relieved while travelling, as well as accelerations and other train-service novelties.

Dealing first with the London Midland and Scottish Railway, three designs call for attention. The first (fig. 1) is a new class of tank engine for heavy suburban and steep gradient branch line traffic, and for suitable main line duties. In many respects it is based upon the useful « 13 000 » class of 2-6-0 mixed-traffic tender engines introduced a few years ago, but applied with side tanks and a bunker carried on a four-wheeled bogie so as to produce the 2-6-4 wheel type. Designed by Sir Henry Fowler, K. B. E., Chief Mechanical Engineer, London Midland & Scottish Railway, 25 of these engines are now in service. They have outside cylinders, with piston valves above, operated by Wal-

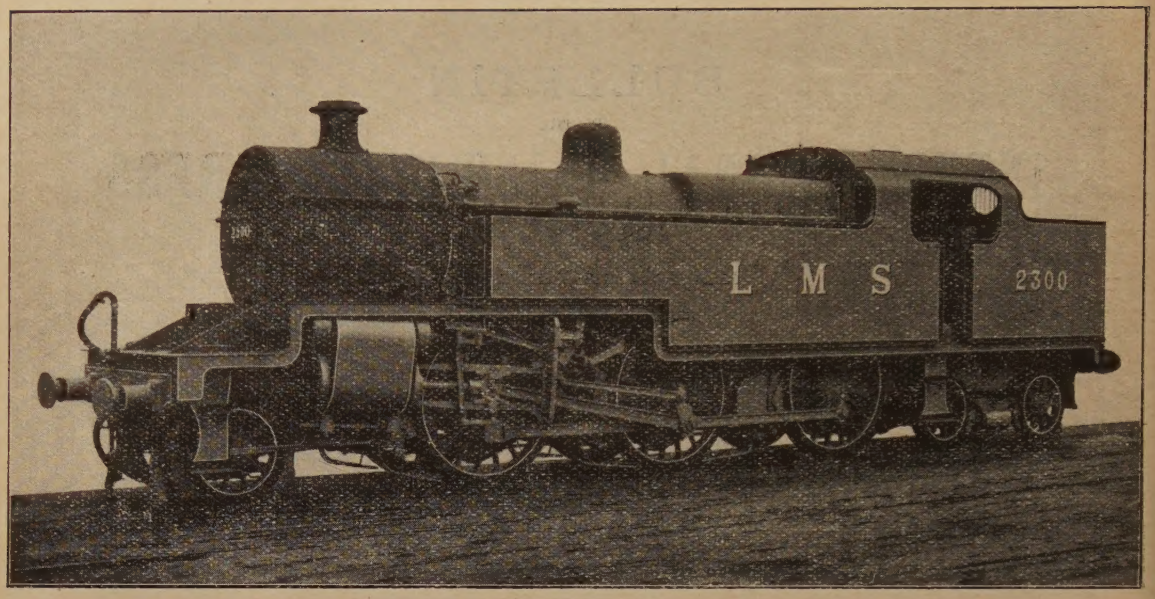


Fig. 1. — 2-6-4 superheater tank engine, London Midland & Scottish Railway.
Sir Henry Fowler, K. B. E., Chief Mechanical Engineer.

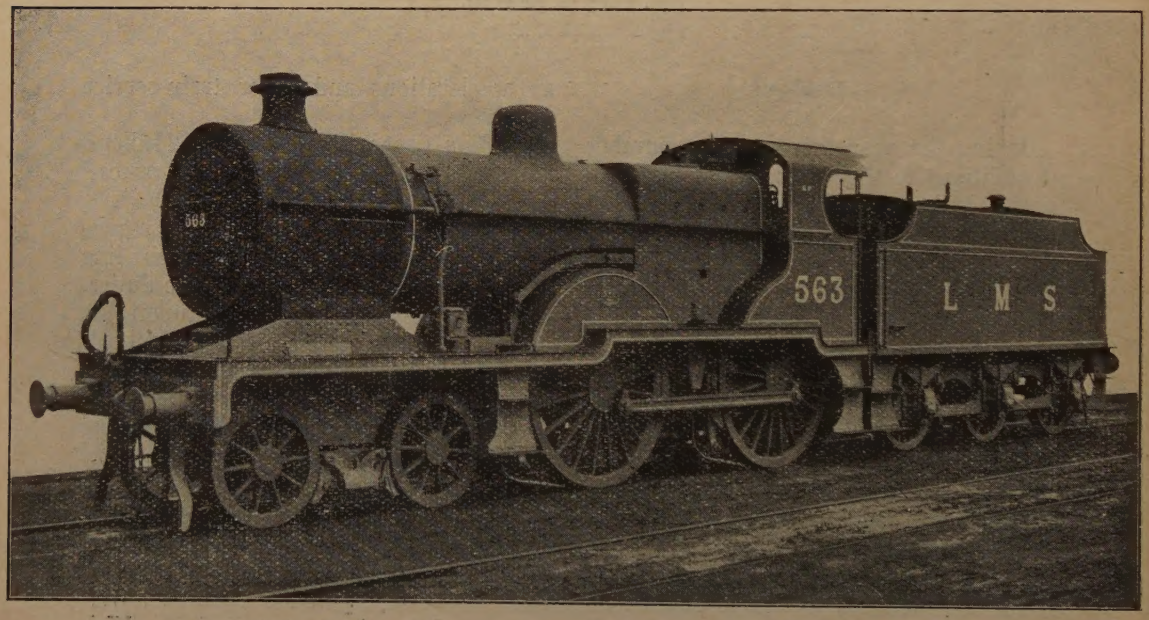


Fig. 2. — New 4-4-0 main line passenger locomotive, London Midland & Scottish Railway.
Sir Henry Fowler, K. B. E., Chief Mechanical Engineer.

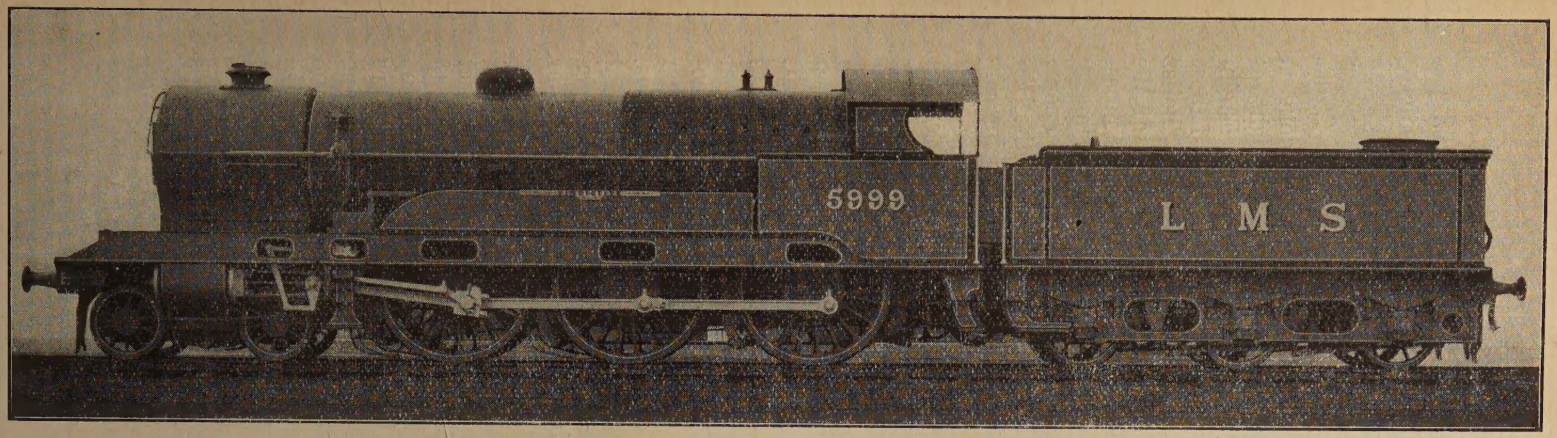


Fig. 3. — Rebuilt four-cylinder 4-6-0 locomotive, London Midland & Scottish Railway.
Sir Henry Fowler, K. B. E., Chief Mechanical Engineer.

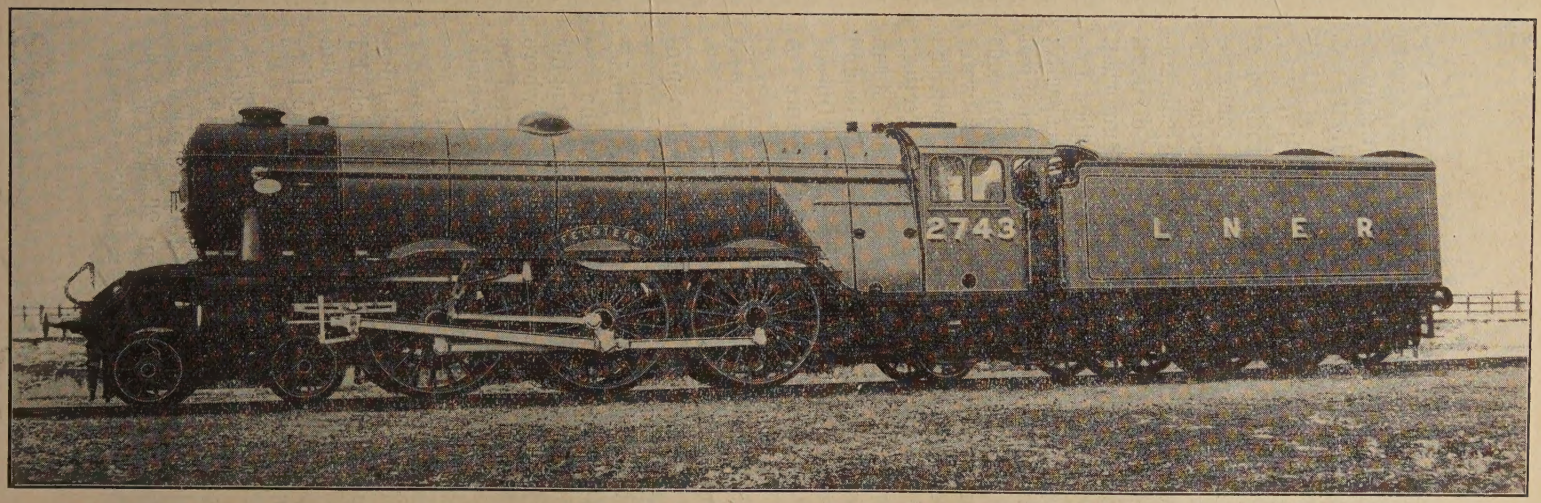


Fig. 4. — New three-cylinder 4-6-2 locomotive, London & North Eastern Railway.
Mr. H. N. Gresley, C. B. E., Chief Mechanical Engineer.

schaerts valve gear. The boiler is a standard design working at 200 lb. per square inch, and, of course, fitted with superheater. The firebox is of Belpaire design and carries Ross « pop » safety valves. The coupled wheels are 5 ft. 9 in. diameter, so that the engines can, when required, reach and maintain comparatively high speeds, though they are intended mainly for dealing with substantial loads and to work over difficult routes as found on several important suburban and branch lines. Other features are : 2 000 gallons water capacity; 3 1/2 tons coal capacity; mechanical lubrication to cylinders and piston rods and to the coupled axle boxes; water scoops to enable water to be collected from track troughs in either direction; large and comfortable cab; and steam brake acting on all engine wheels and vacuum brake control for train. One of these engines is named « Prince of Wales », owing to the fact that His Royal Highness visited Derby Works when it was nearing completion.

The second design (fig. 2), also produced by Sir Henry Fowler, is a development of a standard inside cylinder 4-4-0 tender engine class to meet the continued need on many lines for an engine of moderate size and able to work where bigger classes could not be operated or were not justified. This class constitutes a useful one without special features, but able to meet the requirements of certain services which were beginning to need new motive power but which did not justify the use of the large and powerful engines provided for the heavier and more arduous duties.

The third London Midland & Scottish Railway design is really a rebuild of an older standard class, the « Claughton » design introduced about 20 years ago by the late Mr. C. J. Bowen Cooke for working heavy express traffic on the late London & North Western Railway. Several of these engines have now been fitted by Sir Henry Fowler with larger boilers, and reconstructed in certain other respects. The work has been done at Crewe Works under the oversight of Mr. H. P. M. Beames, Mechanical Engineer, Crewe. Figure 3 shows one of these engines. The fitting of the new boiler adds about 2 tons to the weight of the engine. Its greater height makes it necessary to reduce the height of the chimney and steam dome. Two Ross patent « pop » safety valves are mounted upon the Belpaire firebox. Experiments are being carried out on the London Midland & Scottish Railway with the Caprotti valve gear, and several of these reboilered engines have been fitted with this equipment.

In other respects, there is not much of special importance to record in regard to the London Midland & Scottish Railway. A notable system of progressive locomotive repair has been adopted at Crewe Works, whereby over 600 locomotives per annum can be dealt with on the basis of complete overhaul in 12 days. Incidentally, it may be mentioned that it has been decided to paint passenger engines black instead of red, except for the four or five principal classes, for which the red livery introduced in 1923 is retained. Further, in view of the fact that tenders are not now confined to individual engines so closely on this line as on others, the engine numbers are now shown on the sides of the engine cabs or tanks, the letters « L. M. S. » alone appearing on the tenders. This practice is being applied to all engines of this company. A further item of interest is that all the fifty « Royal Scot » locomotives described last year are now in service and have been named, 25 after regiments of the British Army, and

25 after early locomotives of historic interest. These latter carry small plates having illustrations of the early engines whose names they bear and a few explanatory words.

Dealing now with the London & North Eastern Railway, principal interest attaches to the new 4-6-2 engines designed by Mr. H. N. Gresley, C. B. E., Chief Mechanical Engineer. In general, they represent the application to new engines of the design which resulted from the fitting with a new boiler, pressed to 220 lb. per square inch, of No. 4480, *Enterprise,* illustrated and described last year. Several new engines of this class are now in service and one of these is illustrated in figure 4. This engine is, further, one of those fitted with a corridor tender, so that it can be used for the London-Edinburgh non-stop run of 392.7 miles, the world's record for everyday schedules appearing in the public timetables. These tenders are built up somewhat higher than usual and have at one side a corridor which is vestibuled with the train, so that relieving enginemen can make their way to the footplate when they are due and take over driving and firing duties. The need for this arises from the fact that continuous driving responsibility for over 8 hours could not reasonably be placed upon one pair of men. The engine crew off duty travels in a reserved compartment in the train.

During the year ten 4-6-0 engines, practically of the « 1500 » class introduced in 1912 by the late Mr. S. D. Holden for service on the late Great Eastern Railway, were constructed by Beyer, Peacock & Co. Ltd., with certain modifications made by Mr. H. N. Gresley, as Chief Mechanical Engineer, London & North Eastern Railway. They are intended for service on the Great Eastern section. Among the modifications may be noted the raising of the framing over the coupling rods to facilitate access to the coupling rod crankpin lubricators. Several of these engines are fitted with Lentz valves instead of piston valves.

Just before the year closed, these were followed by a further series of 4-6-0 engines for use on the same section. But they were built by the North British locomotive Co. Ltd, and represent a substantial development upon the older design, including the use of three cylinders and other features new to the Great Eastern section. One of these engines is illustrated in figure 5. It has been built to the maximum axle weights permitted on the Section, having regard to the reduced hammer blow secured by the use of the three-cylinder arrangement. It was essential that the overall length should not exceed that of existing engines, for which reason the small type tender employed on the Great Eastern section has been used. The outside cylinders drive on to the second coupled axle, and the inside cylinder the leading coupled axle. The inside piston valve is operated from the outside mechanism in accordance with Mr. Gresley's well known arrangement. As in the case of the « Shire » class 4-4-0 locomotives described last year, the inside valve gear is arranged behind the cylinder, which is placed well forward and the crosshead and slide bars are under the smokebox. The valve gear used has greatly simplified the arrangement and has made any inside valve motion unnecessary. Nickel chrome steel has been employed for the connecting and coupling rods, which are of similar design to those used on the *Pacific* engines. The tractive effort developed at 85 % of the boiler pressure is 25 380 lb., this comparing with the figure of 21 969 lb. developed by the « 1500 » class, the weight of which for the engine only

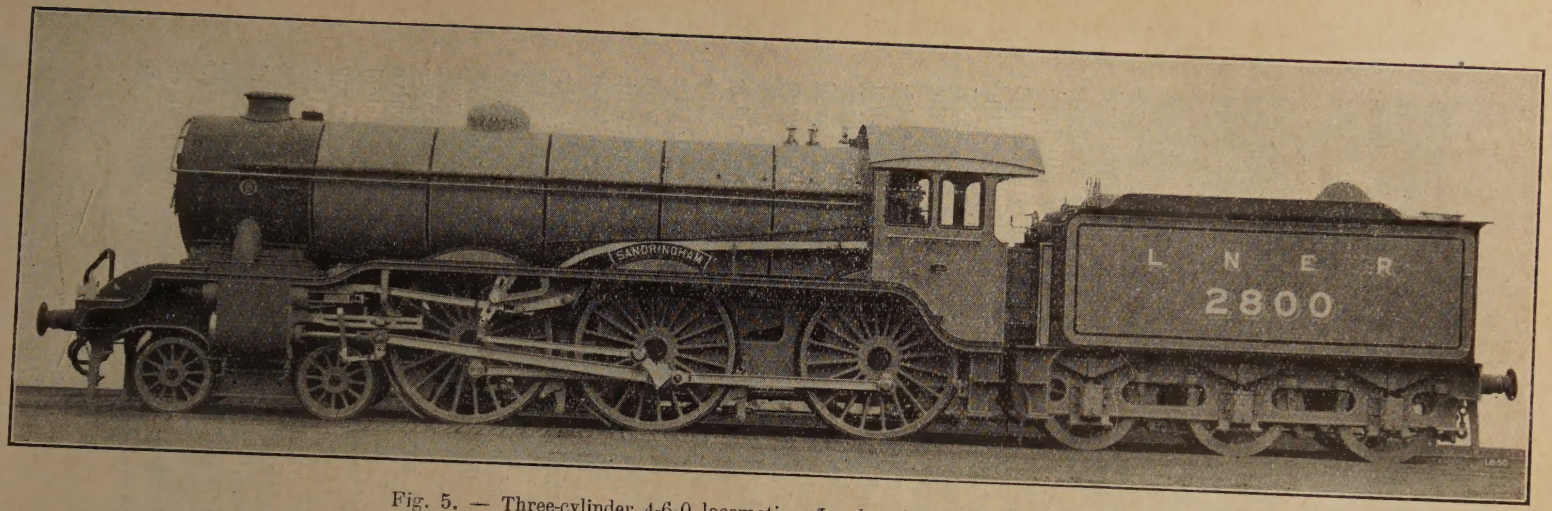


Fig. 5. — Three-cylinder 4-6-0 locomotive, London & North Eastern Railway.
Mr. H. N. Gresley, C. B. E., Chief Mechanical Engineer.

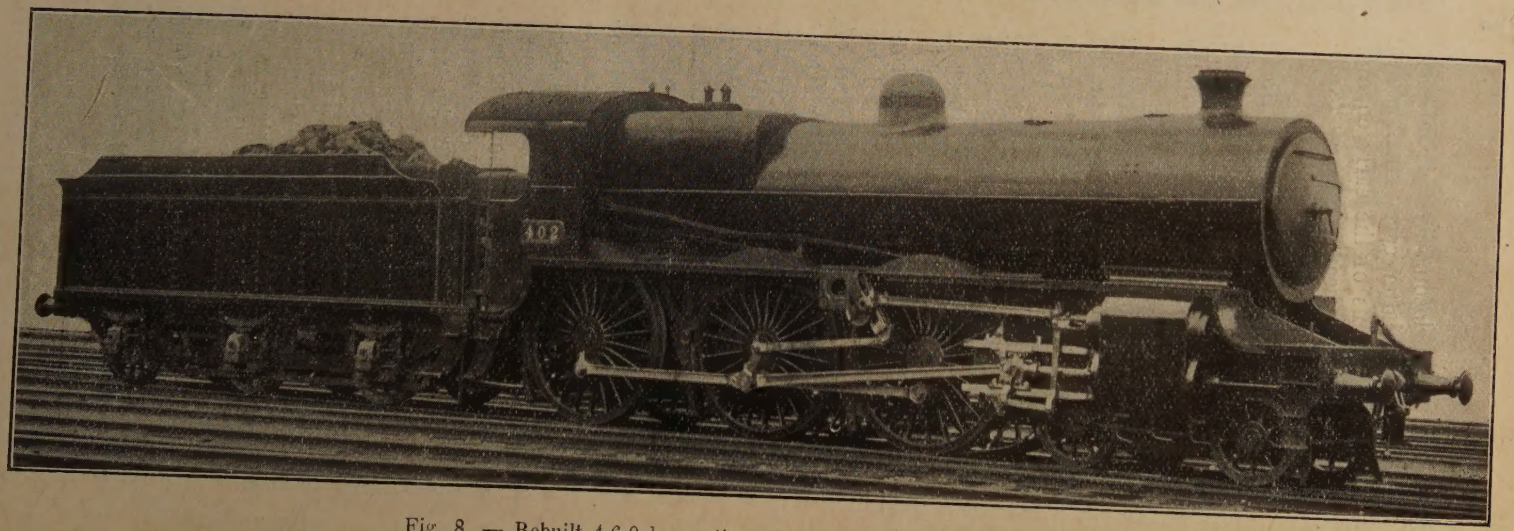


Fig. 8. — Rebuilt 4-6-0 locomotive, Great Southern Railways, Ireland.
Mr. J. R. Bazin, Chief Mechanical Engineer.

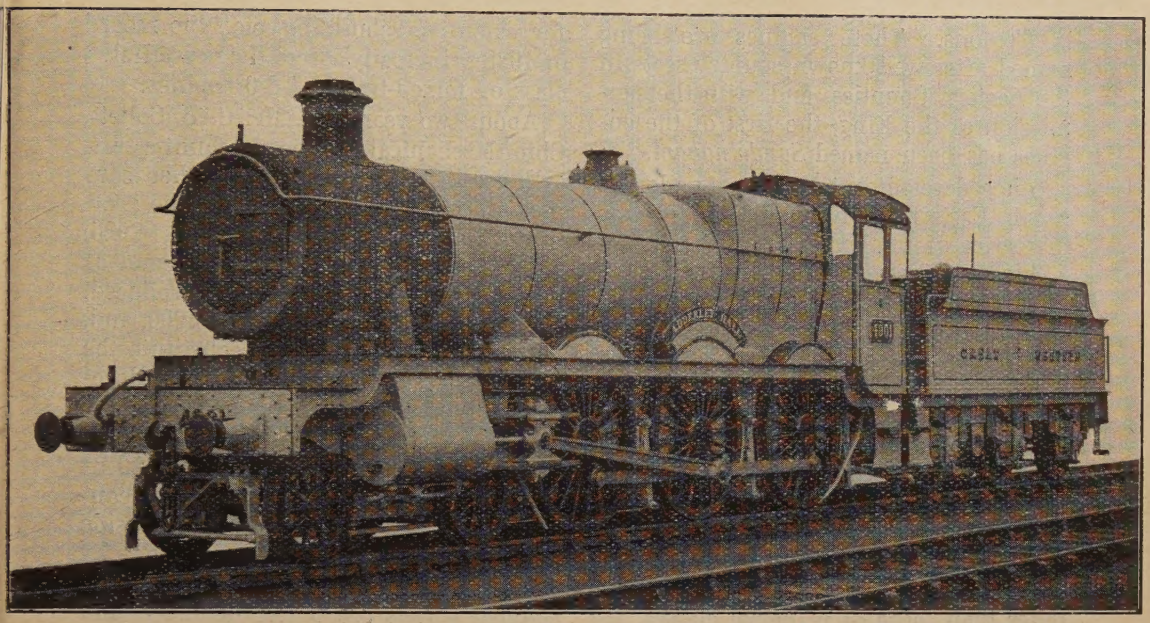


Fig. 6. — Two-cylinder 4-6-0 mixed-traffic engine, Great Western Railway.
Mr. C. B. Collett, O. B. E., Chief Mechanical Engineer.

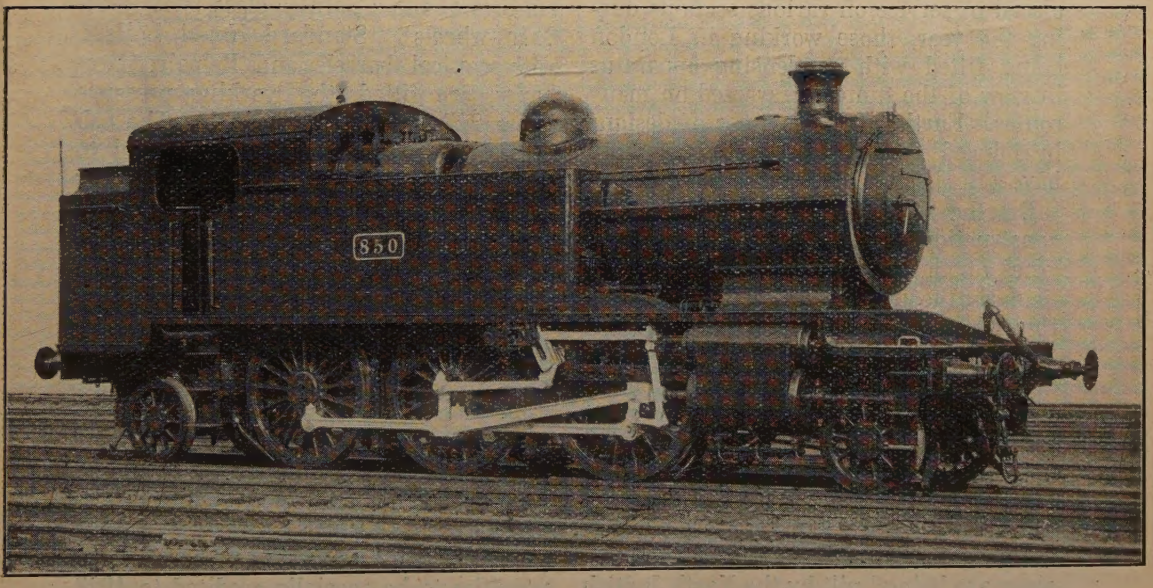


Fig. 7. — 2-6-2 tank engine, Great Southern Railways, Ireland.
Mr. J. R. Bazin, Chief Mechanical Engineer.

is 63 tons. These engines are being named after well known country seats in the Eastern Counties, and, with the permission of the King, the first of the engines bas been named *Sandringham*.

Other developments on the London & North Eastern Railway are the placing in service of further engines of the new « Shire » class of three-cylinder 4-4-0's, illustrated and described last year. These engines are intended for secondary main line duties but have been employed on a number of heavy trains with satisfactory results. Some of these engines have been fitted with Lentz valves. They are all named after counties, and, as a rule, those named after English counties work in England and those after Scottish counties in Scotland.

On this line, too, passenger engines, other than those of principal classes, are being painted black instead of green as hitherto. A number of further 0-6-2 tank engines have been constructed and placed in service on various sections during the year, those working in London being fitted with condensing apparatus in view of the tunnels traversed on many routes. Further 0-6-0 engines of designs introduced during the past few years have also been placed in service.

On the Great Western Railway new construction has applied mainly to engines of classes introduced earlier, particularly the famous « King » class which figured so prominenlty in the review of 1927. A number of additional engines of the class are now at work and more are contemplated in view of the great efficiency they have shown. Fifty 0-6-2 tank engines have been added to stock, built by Armstrong, Whitworth & Co. Ltd. This design first appeared a few years ago. A number of 0-6-0 tank engines are being built by the North British Locomotive Co., Ltd. Otherwise, except for extensive rebuilding, etc., the record of 1928 principally covers the new « Hall » class of mixed-traffic 4-6-0 engines.

About two years ago, Mr. C. B. Collett, Chief Mechanical Engineer, rebuilt a two-cylinder 4-6-0 engine with smaller coupled wheels, and as a result of the good work done by this engine, No. 2925, *Saint Martin*, construction is in hand of new engines to the design thus produced. No. 2925 has been renumbered 4900, and, with the new engines, will constitute the « Hall » class of mixed-traffic 4-6-0 locomotives for service on the more steeply graded main lines.

No. 4901 (fig. 6) is the first of 80 of these locomotives which are under construction. The new engines have outside cylinders, 18 1/2 inches diameter by 30 inches stroke, and piston valves. The coupled wheels are 6 feet diameter, and the bogie wheels 3 feet diameter, the bogie, which is spring controlled, being similar in design to the type used on engines of the « Saint » class (with 6 ft. 8 in.-wheels). Standard No. 1 boilers, with conical barrels and Belpaire fireboxes, are fitted, the working pressure being 225 lb. per square inch. The cab is similar in pattern to those fitted to the « King » and « Castle » classes, being provided with side windows and extended roof.

To meet the needs of certain traffic, various 2-6-0 mixed traffic tender and 2-6-2 tank engines have been partially altered and weighted at the front end to increase the adhesion ratio. They are thus prohibited from running on specified routes, but have been rendered more suitable for service on permitted sections. A new class of 0-6-0 tank engine is also in hand.

On the Southern Railway there are no novelties to be specially credited to 1928. Several further engines of the four-cy-

linder 4-6-0 « Lord Nelson » class, described and illustrated last year, have been completed and placed in service. These engines now work most of the heavy Continental expresses between London (Victoria) and Dover or Folkestone, for which services they have shown notable suitability, as loads are heavy, gradients difficult, and traffic hindrances serious, so that a powerful engine is called for, even although the average speeds may not be very high, notwithstanding that on favorable sections of the routes fast running is made. During the year a number of 2-6-4 tank engines were altered to 2-6-0 tender locomotives. Some new three-cylinder 4-4-0 express engines, also 0-8-0 tank engines, are in hand for this railway.

In Ireland, Mr. J. R. Bazin, Chief Mechanical Engineer, Great Southern Railways, has placed in service a 2-6-2 tank engine (fig. 7), which possesses several features of interest. These engines are intended for working short distance heavy passenger traffic. The wheel arrangement is one which is now very unusual for new construction and almost unknown hitherto in Ireland.

Mr. Bazin has also reconstructed one of the four-cylinder 4-6-0 locomotives in use on the Great Southern Railways with two outside cylinders only (fig. 8). The conversion has been made for comparison with other engines in their unaltered condition, and it is found that shed repairs and maintenance costs are reduced. The engine is rather heavier, has a slightly higher boiler pressure, and is fitted with a larger tender. Most of the original dimensions apply, except those of the cylinders, which are 19 1/2 inches diameter and 28 inches stroke, with 10-inch piston valves, instead of four 14 inches diameter and 26 inches stroke, and 8-inch piston valves, with changes incidental thereto.

Apart from engines belonging to the railway companies, two interesting traction experiments may be noted. One is the Kitson-Still 2-6-2 engine, built by Kitson & Co. Ltd., which has been tried on the London & North Eastern Railway. The general idea is that steam is used for starting, the engine then working on the internal-combustion principle through the same cylinders. The heat of the exhaust gases is used for steam generation. The other is the Beardmore Diesel-electric train, used on sections of the London Midland & Scottish Railway for local service, where it was thought that a self-contained electric set could be advantageously utilised, although equipment for general electric traction was not justified. This set is understood to have given very good results. The Ljungström turbine-locomotive, built by Beyer, Peacock & Co., Ltd., has been given further tests on the London Midland & Scottish Railway during the year.

Finally, in this section, reference may be made to the extensive introduction of « Sentinel-Cammell » and « Clayton » steam rail cars, especially on the London & North Eastern Railway. These cars in some cases replace light trains, but are mostly used for supplementary services designed to amplify local facilities. Frequently they carry loads even beyond their seating capacity, and designs are now being introduced which are able to haul a trailer car to increase the capacity of the unit.

II. — **Work.**

Although last year included the introduction of standard non-stop runs which exceeded the long-standing record for distance held for some 20 years by the Great Western Railway for the London-Plymouth run of 225.7 miles, the new

records set up in 1927 were both exceeded in 1928. Thus, the London and North Eastern Railway, which in 1927 operated a non-stop run of 268.3 miles from London (King's Cross) to Newcastle, introduced in May, 1928, down and up expresses which were booked to cover the entire journey between London and Edinburgh of 392.7 miles without intermediate stop of any kind. This was only rendered practicable by providing corridor tenders, as explained earlier, but created a record which seems likely to stand for many years to come, unless the London Midland & Scottish Railway should decide to follow suit, adopting the same means, in regard to non-stop runs between London (Euston) and Edinburgh (399.7 miles by this route) or Glasgow (401.4 miles). The latter company has, indeed, made both of these runs as special performances, in that on 27 April the « Royal Scot » express was run in two sections, 4-6-0 No. 6113, *Cameronian*, working the Glasgow portion right through from London and 4-4-0 No. 1054 taking the lighter Edinburgh portion similarly right through to destination. In each case, the engines carried a third engineman, but, otherwise, no special provision was made beyond increasing the coal capacity of the smaller engine. These runs were made only to show what could be done, and throughout the summer the London Midland & Scottish Railway was otherwise satisfied with scheduling its up and down « Royal Scot » expresses to be run without stop between London (Euston) and Carlisle. The down train actually ran to Kingmoor engine sheds, about a mile beyond Carlisle (Citadel) station (300.8 miles), and the up train from the London & North Western engine sheds south of Carlisle, reducing the non-stop run to 298.2 miles. During the summer this train was also operated on Sundays with the same non-stop schedules.

The London & North Eastern Railway thus retains the record for long non-stop runs scheduled to be made every day, and in both directions, though the London Midland & Scottish Railway can claim the record for the longest runs actually made, though on one occasion only for each trip. The London Midland & Scottish Railway introduced, however, another very long non-stop run, which is, by the way, continued during the winter, whereas the longer runs, both London Midland & Scottish Railway and London & North Eastern Railway, have been discontinued for the time being. This is the run of the 10.30 p. m. « Night Scot » express, which is worked from Glasgow (Central) right through to Crewe (243.3 miles). All these runs therefore exceed the long-standing Great Western run in regard to distance. The last mentioned, however, in view of the availability of the new « King » class locomotives introduced in 1927, was accelerated by five minutes, so that the 225.7 miles had to be covered in 240 minutes. This meant that the first 200 miles had to be run at almost the mile-a-minute rate, allowing for the very severe gradients of the last 30 miles and the substantial loads, so that this run still ranks as the most notable of the non-stop runs exceeding 200 miles in regard to high average speed. The London Midland & Scottish Railway and the London & North Eastern Railway claim, however, the honours in regard to length of run, though, in view of agreements as to times between London and Edinburgh, at speeds which may appear to be somewhat moderate as compared with the schedules of other trains of the companies concerned.

Apart from these exceptional runs, the London Midland & Scottish Railway

operated during the summer (many runs apply all the year round, but not all) 64 trains booked to run over 100 miles without stop, the London & North Eastern Railway 52 and the Great Western Railway 30. Of these, the number exceeding 200 miles was: London Midland & Scottish Railway 4, London & North Eastern Railway 2, and Great Western Railway 2, with two of 199.7 miles. Exceeding 150 miles the figures were: London Midland & Scottish Railway 25, London & North Eastern Railway 8, and Great Western Railway 7. The London Midland & Scottish Railway also ran a train non-stop from London to Holyhead (263.7 miles) on Saturdays when required.

In the matter of speed, the Great Western Railway retained the lead with 61.8 miles per hour between Swindon and London (77.3 miles in 75 minutes), followed by the London & North Eastern Railway with two runs, one of 44.1 miles in 43 minutes, and the other of 22.6 miles in 21 minutes, both at 61.5 miles per hour. Other fastest runs are: London Midland & Scottish Railway, 107.5 miles in 109 minutes, 59.2 miles per hour; London & North Eastern Railway, 175.8 miles in 183 minutes, 57.6 miles per hour; and Southern, 83.8 miles in 90 minutes, 55.9 miles per hour.

For the long non-stop runs the average speeds above 55 miles per hour were: London Midland & Scottish Railway, 189.7 miles at 55.3 miles per hour; 176.9 miles at 56.8 miles per hour; 158.1 miles at 56 miles per hour; 133.4 miles at 55.3 miles per hour; 112.9 miles at 56.5 miles per hour; and 107.5 miles at 59.2 miles per hour. London & North Eastern Railway, 175.8 miles at 57.6 miles per hour; 105.5 miles at 57 miles per hour; 126.8 miles at 55.1 miles per hour; 107.6 miles at 56.6 miles per hour, and 103.1 miles at 56.8 miles per hour. Great Western Railway, 225.7 miles at 56.4 miles per hour; 199.7 miles at 57.1 miles per hour; 173.7 miles at 57.9 miles per hour; 142.9 miles at 57.9 miles per hour; 137.7 miles at 57.8 miles per hour; 133.4 miles at 57.2 miles per hour; 118.3 miles at 59.2 miles per hour; 117.6 miles at 58.8 miles per hour; 106.9 miles at 57.8 miles per hour, and 100 miles at 56.1 miles per hour, together with two slip carriage services which gave an average of 61.1 miles per hour for 106.9 miles.

The Southern Railway has no runs exceeding 100 miles, except one on Saturdays between London and Bournemouth, 108 miles in 132 minutes, but it has a good many shorter runs timed at 50 miles per hour or higher. The other railways also have many shorter runs timed very fast, and in the case of the Great Western Railway there are two slip carriage services of 106.9 miles in 105 minutes, and one off the 10.30 a. m. from Paddington at Westbury, 95.6 miles in 94 minutes, all exceeding 60 miles per hour. There is also a run of 91 miles in the same number of minutes, average 60 miles per hour, between Paddington and Kemble.

During the year many long engine workings have been instituted besides those occasioned by the very long non-stop runs mentioned. On the London Midland & Scottish Railway engines thus worked turns such as Carlisle-Glasgow, Glasgow-Crewe and Crewe-Carlisle, and the London & North Eastern Railway turns such as Newcastle-Edinburgh, Edinburgh-Grantham and Grantham-Newcastle thus exceeding 400 or even 500 miles, and other variations, apart from the necessities of the very long non-stop runs (with, of course, changes of enginemen).

The writer did not travel on either of the special non-stop runs between Euston and Glasgow and Edinburgh mentioned, and exact times, beyond the fact that schedule was maintained, have not been published. He did travel, however, with the up Sunday « Royal Scot » express, non-stop from south of Carlisle to London, and this journey may be briefley outlined.

This train has 15 minutes longer than on weekdays, to allow of possible delays for permanent way operations so often carried out on Sundays, and as one such delay occurred it may be said that the work was fully equal to that of a weekday journey. The load, too, was the standard full load, 15 bogie coaches of the latest types. Nine of these were brought from Glasgow (Central) to Carstairs by « Royal Scot » class engine No. 6131, *Planet*, this stage of 28.8 miles (never taken very fast and including delays) occupying 53 minutes. Six coaches from Edinburgh were then attached,making the load about 440 tons to be worked to London. The fairly hard 17.2 miles to Beattock Summit took 32.1 minutes. Thence the 49.7 miles to Carlisle, including a relaying slack approaching, were covered in 50 minutes. A stop was made at the engine sheds two minutes later, when No. 6134, *Atlas*, of the same class, took charge for the non-stop run to London, 298 miles. In the neighbourhood of Penrith, temporary single line working was in force, necessitating slacks to walking pace to take on and put off a pilotman. For this and other reasons the 30 miles to Shap Summit took 62 minutes, but the next 58.7 miles (with one intermediate check) to the Preston station slack were run in 62.3 minutes. Thence to Crewe the 41.1 miles occupied 60.6 minutes. With further checks, the 24.5 miles to Stafford took 34.3 minutes. The 51 miles to Rugby were covered in 54 minutes, and the remaining 82.5 miles to London, with several incidental checks, were completed in 92 minutes, thus completing the run practically to schedule.

In the case of the London & North Eastern Railway, also, the writer's experience of the « Flying Scotsman » run non-stop between London and Edinburgh, 397 miles, was in the up direction. On the 10.0 a. m. up « Flying Scotsman », non stop from Edinburgh (Waverley) to London (King's Cross), No. 4472, *Flying Scotsman*, was most appropriately used on the day he travelled. It had, of course, a corridor tender so that relieving enginemen could take charge about half-way. The load was about 380 tons. To Berwick, including the Cockburnspath bank to Penmanshiel tunnel and a permanent way slack for bridge renewal works at East Linton, the 57.5 miles occupied 74 minutes. Thence to Newcastle the 66.9 miles, with several usual slacks and easy running for the last few miles, were covered in 82.7 minutes. This was the writer's first experience of passing through Newcastle Central station without stopping. The next 36 miles to Darlington took 49.9 minutes, and the 44.1 miles onward to York were run exactly in 52.1 minutes. To Doncaster the 31.9 miles were run in 44 minutes, the 50.5 miles to Grantham occupied 64 minutes, and the 29.1 miles to Peterborough took 34.1 minutes. At all these places speed was severely reduced, unusually except at Peterborough, where it is essential. The final 76.4 miles into London were covered in 92.9 minutes. The total time from Edinburgh to London, 392.7 miles, was therefore 1 minute under the scheduled time of 8 h. 15 m. for this, the world's record for a non-stop run booked in the public timetables

and to be performed daily in both directions.

On the well-known Great Western Railway 10.30 a. m. « Cornish Riviera » express, on its accelerated schedule, No. 6008, *King James II*, started with about 430 tons. For the first few miles running was very steady, though Reading, the first reduced speed station, was passed in 35.3 minutes (36 miles). Thence to Savernake, generally adverse gradients, the 34.1 miles took 37 minutes. The next 24.1 miles to Westbury were run in 22.5 minutes. Here two vehicles were slipped, reducing the load to 350 tons. Speed has to be reduced at Westbury, also at Frome, so that this stage of 5.7 miles took 6.5 minutes. Thence to Taunton the 41.6 miles were run in 41.1 minutes. The 10.9 ascending miles to Whiteball box took 12.3 minutes. Down to Exeter the 19.9 miles occupied 19.1 minutes, a point of interest being that Exeter (St. David's) was passed at speed, as is now permissible. The 173.7 miles from London had thus been covered in 171.7 minutes, including three reduced speed stations, a fair percentage of more or less steep gradients, and with 430 tons for nearly 100 miles and 350 tons for the rest of the run.

From Exeter to Newton Abbot running is always rather steady because of curves, though gradients are easy. This stage of 20.2 miles therefore took 22.5 minutes, and the complete run of 193.9 miles so far from London had taken 194.3 minutes. Then comes the terrifically graded and very difficult stage of 31.8 miles to North Road station, Plymouth. This stage, notwithstanding its gradients of 1 in 42, 53 and the like and with corresponding down grades which, because of their severity and in view of curves, must be taken carefully, were run in 44.8 minutes, so that when we made our first stop at Plymouth, 225.7 miles from London, the total time occupied was 239 minutes, a gain of 1 minute on the longest non-stop run in Great Britain which also ranks as one of the fastest schedules in force for a long distance run.

While dealing with the Great Western Railway, a few notes may be given concerning other notable runs on that line. Another engine of the same class, No. 6007, *King William III*, with about 470 tons, on the 3.30 p. m. from Paddington, passed Reading (36 miles) in 38.4 minutes, and then covered the more or less difficult stage of 34.1 miles to Savernake in 36.5 minutes. Thence to Westbury, with a permanent way slack approaching as well as the usual slack through the station, the 24.1 miles were run in 22.9 minutes. Here, two vehicles were slipped, reducing the load to 400 tons. To Frome (slack) the 5.7 miles occupied 7 minutes. A bad check was experienced near Castle Cary, while a stop became necessary outside Taunton, so that the 41.4 miles from Frome took 44.2 minutes. Eventually, with a further check approaching Exeter, that station was reached in 188 minutes from London (173.7 miles), which, in view of the load and hindrances, was a very good performance, though about 8 minutes had been lost on schedule.

In the opposite direction another « King » class engine No. 6012, *King Edward VI*, with, however, only about 250 tons ran from Exeter to Taunton in 34 minutes (30.8 miles), covered the 27.6 miles to Castle Cary in 30.6 minutes, the 19.7 miles to Westbury in 24.5 minutes, the 58.4 miles to Reading in 61.1 minutes, and the 36 miles to London in 42.1 minutes with delays, all these being start to stop stages. On another up run, No. 4084, *Aberystwyth*

Castle, of the earlier « Castle » class, with about 350 tons, ran from Exeter to Taunton (30.8 miles) in 35.6 minutes. Adding a vehicle to be slipped at Newbury, the 41.6 miles took 48.1 minutes. Both at Frome and Westbury speed reduction is necessary, but the 58.4 miles to Reading (one vehicle slipped at Newbury) occupied 58 minutes. Thence to London the 36 miles, including delays, occupied 37.5 minutes. The 142.9 miles from Taunton were therefore run in 150.7 minutes, including delays.

Two interesting runs on two-hour London-Birmingham expresses may also be noted. The same engine was concerned in each case, though not on the same day. This was No. 4071, *Cleeve Abbey*, one of the last of the series of four-cylinder 4-6-0 engines prior to the introduction of the developed « Castle » class. With 350 tons, the first 26.5 miles to passing High Wycombe took 33.2 minutes, although no high speed is practicable for the first 4 or 5 miles. Thence to Banbury, where a vehicle was slipped at speed, the 41 miles took 42.5 minutes. The 19.8 miles to Leamington (reduced speed and slip two coaches) took 18.9 minutes and the remaining 23.3 miles to Snow Hill station, Birmingham, were run in 25.5 minutes, so that the complete run of 110.5 miles had occupied exactly the 120 minutes allowed. Returning with about 250 tons, the same overall time was allowed, but with an intermediate stop at Leamington. This stage of 23.3 miles from Snow Hill station took 25.2 minutes. From Leamington the 60.8 miles to passing High Wycombe (speed reduction) took 58.4 minutes, and the final 26.5 miles to Paddington station, including one check, usual final slow running, and a momentary stop outside the terminus, occupied 30 minutes. Nevertheless, the arrival in the terminus was a trifle under the booked schedule.

Dealing now with some further London Midland & Scottish Railway runs, on one of the Scottish sleeping car expresses, No. 6107, *Argyll and Sutherland Highlander* (« Royal Scot » class), had a load of 490 tons from London (Euston). Thence to Tring summit (31.7 miles) took 43.7 minutes, the 15 miles to Bletchley 13.7 minutes, and the 35.8 miles to Rugby (slack) 39.1 minutes. The 51 miles onwards to Stafford occupied 56 minutes, and Crewe was reached 28.5 minutes later. The 158 miles from London had thus been covered in 181.1 minutes. With 450 tons the same engine covered the 51.1 miles to Preston (slack) in 60.3 minutes, and the increasingly difficult 40 miles to Oxenholme in 45.2 minutes. Owing to the load, pilot assistance was taken to Shap Summit, the 18.7 miles occupying 29.4 minutes. Detaching the pilot, No. 6107 passed through Carlisle station at reduced speed 33 minutes later (31.3 miles), continuing to Kingmoor engine sheds, about a mile beyond, to change engines.

From Kingmoor two compound 4-4-0 engines passed Beattock station (39 miles) in 44.2 minutes, and stopped at the summit of the Beattock bank, 10 miles at about 1 in 70, 20.6 minutes later. Here one engine was detached and the other took on the very big load alone. The remainder of the route is, however, very complex and is not timed unduly fast.

On a Liverpool express another « Royal Scot » engine, No. 6147, *Courier*, had about 350 tons to work from Crewe to London. To Stafford the 23.5 miles occupied 28.5 minutes; onwards to Rugby the 51 miles were run in 52.3 minutes, and the concluding 83.2 miles to Euston occupied 88.9 minutes.

A Claughton class 4-6-0, No. 5901, *Sir Robert Turnbull*, with 300 tons, passed Tring summit (31.7 miles) in 42.4 minutes from London, ran the next 15 miles

to Bletchley in 13.8 minutes, and passed Rugby (35.8 miles) at reduced speed 36.3 minutes later. Thence to Stafford (51 miles) took 56 minutes, and the 24.5 miles to Crewe 28.5 minutes. The 158 miles from London to Crewe had therefore been run without stop in 177 minutes.

A few further runs on the London & North Eastern Railway may now be briefly considered The 1.15 p. m. « Midday Scotsman » from King's Cross was worked not by a 4-6-2 but by a 4-4-0, No. 4331, piloting a 4-4-2, No. 4457. The load was, however, a good 450 tons. To Potters Bar summit slight delays were experienced, so that the 12.7 miles occupied 24 minutes. Thence to the usual severe slack at Peterborough, the 63.7 miles occupied exactly 60 minutes. Onwards to Stoke summit the 23.7 miles, generally ascending, were covered in 31.7 minutes, and Grantham, first stop, was reached in 122.2 minutes (105.5 miles). With the same engines, the 50.5 miles to passing Doncaster were run in 56.2 minutes, and, with intermediate checks, York was reached 49 minutes later, and in 105 minutes from Grantham, 82.7 miles. 4-6-2 No. 2573, then took charge, and ran from York to Darlington, 44.1 miles, in 52 minutes, start to stop. Thence to Newcastle, with delays, the 36 miles took 50 minutes. With a similar engine the 66.9 miles to Berwick were covered in 77 minutes. thence to Drem the 39.7 miles took 51.5 minutes, and the final 17.8 miles to Edinburgh were run in 23.5 minutes, these being start to stop stages.

On one of the up sleeping car expresses, the 17.8 miles from Edinburgh to Drem occupied 25 minutes. Here two vehicles were attached, bringing the load to about 470 tons. Starting again, Berwick was passed in 51.4 minutes (39.7 miles) and the next 65 miles, to a stop near Newcastle, occupied 76.6 minutes. Leaving Newcastle, the 36 miles to passing Darlington occupied 46 minutes, and the next 44.1 miles to York were run in 45.6 minutes. A third 4-6-2, No. 4474, *Victor Wild*, then took charge for the journey to London. From York the 82.7 miles to Grantham occupied 105.4 minutes, but with several usual and special checks. From Grantham to passing Peterborough slowly, the 29.1 miles took 32 minutes. Thence to passing Potters Bar, 63.7 miles, occupied 77 minutes, and London was reached 18.5 minutes later (12.7 miles).

On one of the night sleeping car expresses from London No. 2543, *Felstead* (fig. 4), with a good 500 tons, covered the King's Cross-Peterborough stage (76.4 miles) and the Peterborough-Stoke stage (24.7 miles) in 82 and 30.7 minutes respectively, reaching Grantham, first stop, in 120.8 minutes from London. Thence, Doncaster (50.5 miles) was passed in 60.5 minutes,including checks near Retford, and, with further checks, York was reached in 98 minutes from Grantham (82.4 miles).

No. 2572, *St. Gatien*, with 450 tons, ran the 66.9 miles from Newcastle to Berwick in 77 minutes, and, starting again, covered the 39.7 miles to a stop at Drem in 51.7 minutes notwithstanding the very stiff climb to Penmanshiel tunnel involved by the Grantshouse bank. The remaining 17.8 miles to Edinburgh (Waverley) took 26 minutes.

No. 2401, one of Sir Vincent Raven's 4-6-2's, with 530 tons, ran from Selby to Doncaster, with delays, in 27 minutes (18.4 miles). Thence a Gresley 4-6-2, No. 4478, *Hermit*, ran to Grantham, 50.5 miles, in 55.7 minutes. The next stage of 29.1 miles to Peterborough took barely 33 minutes, the 24.7 easy miles

from Stoke summit being covered in 22 minutes, with an easy approach to Peterborough. Here the load was reduced to about 400 tons, and with permanent way slacks near Huntingdon, the 73.8 miles to a stop at Finsbury Park were run in 88 minutes. A similar engine, No. 2551, *Prince Palatine*, with 420 tons from London passed Peterborough slowly in 82.3 minutes (76.4 miles), covered the 24.7 ascending miles to Stoke summit in 26.3 minutes and reached Grantham, the first stop, in 120.9 minutes (105.5 miles) from King's Cross. Thence to Doncaster the 50.5 miles, start to stop, occupied 53.2 minutes.

On the Great Eastern section, with a Yarmouth express, No. 8550 (4-6-0) had about 270 tons to work non-stop. To Ingrave summit, with slight delays, the 19.3 miles occupied 29.5 minutes. Thence to passing Ipswich (reduced speed) the fairly difficult 49.4 miles occupied 50.1 minutes. Thence, over a complicated and rather difficult route, the 40.5 miles to passing Beccles took 53.3 minutes and the final 12.6 miles took 17.5 minutes. The completed run of 121.8 miles had therefore occupied 148.5 minutes, quite a good figure for the route in question.

The writer had only one experience with a « Shire » class 4-4-0 and that was in Scotland. No. 270, *Argyllshire*, with about 240 tons, was booked to make the non-stop run from Edinburgh (Haymarket station) to Glasgow (Queen Street). It was badly checked about half-way, but passed Cowlairs (44.6 miles) at 10 miles per hour in 55.5 minutes, thence descending the very steep gradient of 1 in 45 for over a mile most carefully and reaching the terminus in exactly the 61 minutes allowed.

On the Southern Railway, although there were then three or four engines of the « Lord Nelson » class in service on the heavy Continental expresses between Victoria station, London, and Dover, the trains by which the writer travelled were worked by « King Arthur » class engines. On the 10.45 a. m. special express, No. E 767, *Sir Valence*, had nine Pullman cars, with other vehicles, which brought the load up to about 470 tons. As far as Orpington the route is a very complicated one, so that the 14.9 miles took 26 minutes. About half of the distance onwards to Sevenoaks is very steep, but the 8.2 miles were run in 13.1 minutes, and the next 7.5 miles to Tonbridge (slack) took 9.5 minutes. The 26.6 miles to Ashford, including a permanent way slack, took 27.1 minutes, and the remaining 21.8 miles to Dover were completed in 23 minutes. Returning, No. E 769, *Sir Balan*, of the same class, with 440 tons, passed Ashford (21.8 fairly difficult miles) in 30.4 minutes, and with an intermediate permanent way slack covered the 26.6 miles to Tonbridge (slack) in 28.7 minutes. The remaining 30.6 miles to London were completed in 52 minutes, quite a good performance allowing for the adverse gradients, frequent enforced speed reductions, route complications and one or two additional checks.

On the « Southern Belle » express between London and Brighton, a new 4-6-0, No. E 800, *Sir Meleas de Lille*, had about 390 tons. The 10.5 miles from Victoria to passing East Croydon occupied 16.8 minutes owing to the usual traffic delays. Near Quarry tunnel there was a rather severe delay, so that the 11.4 miles to passing Earlswood took 17 minutes. Thence to passing Haywards Heath the 16.1 miles were run at sustained high

speed in 16.5 minutes. To Brighton the 12.9 miles took 13.7 minutes. Three minutes had been taken over the allotted 60 minutes from London to Brighton, but with compensating delays.

LEADING DIMENSIONS OF LOCOMOTIVES ILLUSTRATED AND DESCRIBED.

T = Tank engine. — R = Rebuilt.

Figure.	RAILWAY.	Type.	Cylinders. Diameter and stroke (inches).	Diameter of coupled wheels.	Heating surface (square feet).			Grate area (square feet).	Steam pressure (lb. per square inch).	Weight (engine only) in working order (tons).
					Tubes.	Fire box.	Super-heater.			
1	London Midland & Scottish.	2-6-4 T	19 × 26	5 ft. 9 in.	1 083	137.25	266.25	25	200	88.25
2	— — —	4-4-0	19 × 26	6 ft. 9 in.	1 033.75	123.50	252.75	21.1	180	54.1
3	— — —	4-6-0 R	15 3/4 × 26 (4)	6 ft. 9 in.	1 550	183	365	30	200	79.1
4	London & North Eastern. .	4-6-2	19 × 26 (3)	6 ft. 8 in.	2 522	215	706	41.25	220	96.25
5	— — — . .	4-6-0	17 1/2 × 26 (3)	6 ft. 8 in.	1 508	168	344	27.5	200	76 3/4
6	Great Western.	4-6-0	18 1/2 × 30	6 ft.	1 686.60	154.78	262.62	27.07	225	75
7	Great Southern, Ireland . .	2-6-2 T	17 1/2 × 28	5 ft. 6 in.	697	119	240	19.75	160	71.5
8	— — — . .	4-6-0 R	19 1/2 × 28	6 ft. 7 in.	1 590	158	350	28	180	73.5

[625. 145.2 & 669. 1]

Special hard wearing steels for use in points and crossings, [1]

By PAUL MARTHOUREY,
CIVIL MINING ENGINEER,
PRINCIPAL ENGINEER OF THE GENNEVILLIERS STEEL WORKS.

Figs. 1 to 35, pp. 233 to 249.

(*L'Industrie des Voies ferrées et des Transports automobiles.*)

FOREWORD.

General remarks on the phenomenon of wear.

The wear of rails is one of the most controversial of metallurgical questions, and although volumes have been written on the subject, the laws governing it are still to be determined.

The question is whether the wear depends upon the mechanical characteristics of the metal, upon the way the steel has been made, upon the metallographical texture, or upon the conjunction of all these properties.

It would appear that the influence of the *mechanical characteristics of the instantaneous type* has been thoroughly investigated without any real success having resulted from the very many enquiries made, the first of which took place prior to 1875.

We have given as an appendix certain details with regard to the definitions of the *mechanical characteristics of sound steel* (tensile strength and elongation, breaking load, elastic limit and extension, reduction in area, Brinell hardness, resilience, ductility).

Mr. Frémont, in a noteworthy pamphlet, has shewn the influence of the *heterogeneity* of large Thomas steel ingots on the wear and premature fracture of the rails by internal cracking or fissuration, the commencement and growth of which are due to segregations, inclusions and central piping : this investigation brought to light, we believe for the first time, the influence of repeated stresses on the grain of a *fragile and unsound metal* and the shortcomings of the Thomas metal from the point of view of safety for lines over which express trains run.

In the works of Messrs. Breuil and Robin (1919) and Brinell (1921), we can study the relations existing between the wear by abrasion, the *composition of the metal,* and its *metallographical texture.*

All these investigations are obviously of value, even though they deal almost exclusively with rolled Thomas and Martin steels hardened by increased carbon content or by heat treatment, and exclude special steels whether rolled or cast : furthermore, the results obtained (under test conditions often very different from those obtaining in the track) have been *arbitrarily* and *solely considered in conjunction* with the *instantaneous mechanical characteristics* to the exclusion of the characteristics of *fatigue* into which the element of time enters.

(1) Report to the IVth General Technical Meeting of the Union des Voies Ferrées et des Transports Automobiles (Marseilles, 6, 7 and 8 November 1927).

It is therefore very fortunate that the 13 % manganese steel should have come on to the market whilst a conclusion is being awaited to these investigations which are frequently contradictory.

It should be added that the numerous factors that come into play on the « causes » side, and on that of the « materials » make the study of the phenomena of wear extremely complicated.

From the « causes » side, the wear depends upon the shocks, the compression, the speed, the sort of frictional rubbing (abrasion, slipping, rolling) the nature, form and method of attack of the bodies in rubbing contact one upon the other, and their degree of wear.

On the « materials » side, we believe the wear depends upon the whole of the test results under *single stresses* (the usual characteristics of tensile, hardness and shock) and upon *repeated stresses* (exceptional characteristics of fatigue into which the time factor enters).

In our opinion, the manufacture of metal standing up to wear should always be based before all upon the determination of its stress characteristics, which depend first of all upon its careful manufacture, and which are brought to light by metallography.

We think it will be useful to define at this point the fatigue of the metal.

In mechanical construction work as in the track, *we note* that certain details crack or break after more or less long service, under a working stress even much lower than the elastic limit, the electric, magnetic, and metallographic properties of the metal remaining unaltered close to the fracture, known as a « fatigue fracture » and which generally reveals a characteristic smooth surface.

The nature of the fatigue stresses or forces is very varied (tensile, compression, bending, twisting, shock, etc.). They may be simple or compound of varying amplitude, and may act under differing conditions (temperature, shape of the test bar, etc.).

For a given system of conditions, there is a figure defining the « fatigue load » or limiting working load, below which the force can be applied indefinitely without causing fracture.

It will be appreciated that the determination of the fatigue load may be very long since in certain cases of rotating bending, for example, several hundred millions of alternations may be required to get a fracture. As the metals cannot last for ever, this determination of an absolute figure can be replaced with advantage by a comparative test of metals working under the same conditions under high loads, whereby comparable results can be obtained quickly.

In certain cases also, an attempt has been made to define the « fatigue load » by the temperature of heating of the test bar which increases when a certain load is exceeded, whence we are naturally led to introduce the ideas of hysteresis and of decreasing elasticity of the steels.

When a metal revealing hysteresis is subjected to a succession of mechanical cycles, the fraction of potential energy (allied to the decrease in elasticity) dissipated under the form of heat in the distance moved is a function of the complexity of the metal (slag, inclusions) of which in this way it supplies the characteristic previously lacking.

Now the phenomena of wear of the track are marked by a series of deformations and of repeated shocks : under a normal pressure of tyre, in fact, the material in contact becomes deformed,

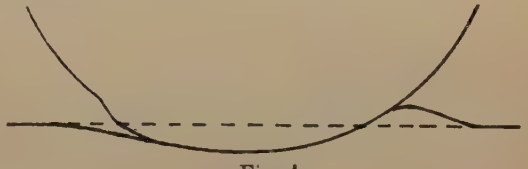


Fig. 1.

and there is a surface of contact resulting in compression of the material in front, and distension in that behind as the wheel rolls forward (fig. 1).

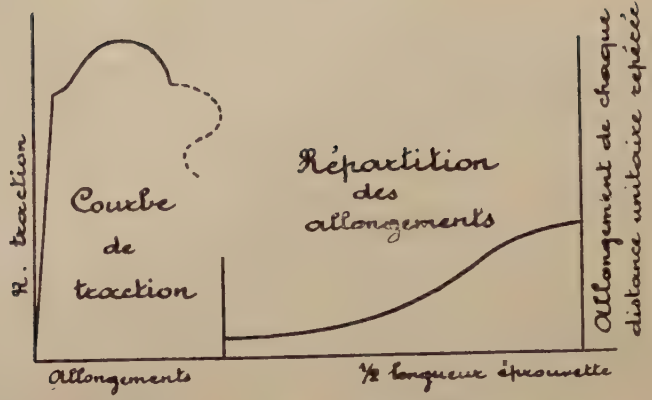


Fig. 2. — Nickel-chrome electric cast steel.

Explanation of French terms : Allongements = Elongations. — Allongement de chaque distance unitaire repérée = Elongation of each unit length marked off. — Courbe de traction = Tensile curve. — Répartition des allongements = Distribution of the elongations. — R. traction = Tensile strengh.

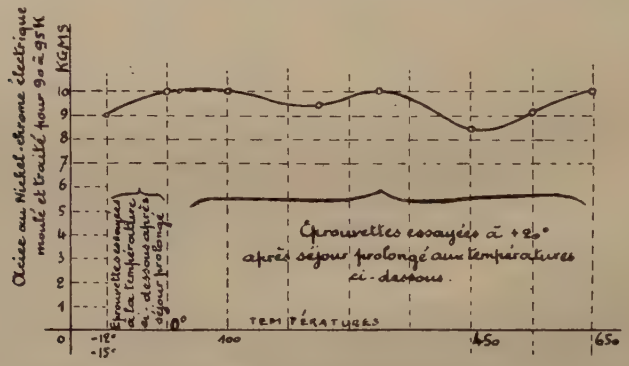


Fig. 3. — *Variations in resilience with the temperature of the cast test piece.*

Explanation of French terms : Acier au nickel-chrome électrique moulé et traité pour 90 à 95 k. = Nickel-chrome electric steel cast and heat treated to give 90 to 95 kgr. (57.15 to 60.32 tons per square inch). — Éprouvette essayée à la température ci-dessous après séjour prolongé = Test piece tested at the temperature below after being kept at it some time. — Éprouvettes essayées à + 20° après séjour prolongé aux températures ci-dessous = Test piece tested at 20° C. (68° F.) after being kept some time at the temperatures below.

Moreover, the sudden change from rolling to slip gives rise to shocks and vibrations which are absorbed by internal friction in the material.

The phenomenon of hysteresis of the steel then intervenes following a law of deformation which is no longer the same under increasing stress as under diminishing stress.

It can therefore be imagined that the open grain revealed by metallographic examination can be the cause of the first beginnings of premature failures under repeated stress, by considerably lowering the working fatigue stress of the coarse grain metal possessing hysteresis to a large degree with marked lowering of the elasticity.

Brinell hardness is evidently needed from the start to stand up to intense traffic and to the speed and weight of the carriages : it gives the metal time to work harden over the whole length of a point or crossing run over in different directions.

The *elastic limit* is one of the most important characteristics of the resistance of the material to crushing, to lateral spreading and to hammering effects under shocks : a steel having a high elastic limit is affected both later and slower than a steel with a low elastic limit.

The elastic elongation coupled to the elastic limit is characteristic of certain carefully melted steels with little falling off of elasticity under repeated loads.

The resilience (recorded in accordance with various formulæ under single or repeated shocks) is, in our opinion, a prime factor as regards wear, not so much directly, but because it is connected with the nature of the molecule and its cement, with the isotropy and inclusions and gas, in a word with the homogeneity of the metal.

In a resilient steel any superficial defect will not develop quickly in depth under the effect of repeated fatigue stresses.

Work hardening is the result of repeated stresses on the running surface (crushing under shock with compression and lateral spreading); the proneness of a metal to work hardening is a function of its nature, of its real strength, and of its elongation with reduction of area which characterises the faculty of local deformation.

In the *work done at fracture* it is therefore necessary to take note of the product of the real strength by the elongation with reduction of area.

Work hardening should not go so far as foliation which is characteristic of a heterogeneous metal of open structure, of which the mechanical characteristics as regards isotropy become reduced through work hardening under the effect of the *laminated inclusions*, which result in wear by the disappearance of the hardened and dead metallic pellicules (figs. 5 to 9).

Finally, the isotropy of a metal is an important phenomenon to consider and a definite function of the method of working up the metal.

I.

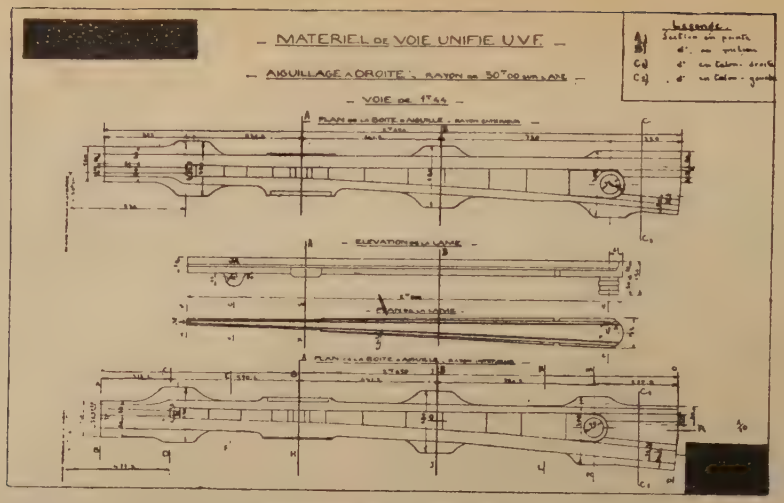
Review of the research carried out to find a steel offering great resistance to wear.

The railway and tramway companies have in view of the complexity of the problem naturally displayed considerable circumspection with regard to the use in the track at special places of cast steel to various formulæ and of different makes, instead of assembled points of rolled steel made by the Thomas or Martin processes.

This care is justified if we reflect a moment upon the accidents that might occur on the one hand, and on the other upon the time required to test a steel in practice in the permanent way : it has led the companies to endeavour to obtain *steel of equal quality to the special steels* in order to make good the more open grain which an unforged cast steel often reveals (fig. 5 to 9).

Every method of melting (converter, Martin furnace and electric furnace) all mixtures (manganese, chrome, nickel and chrome-nickel steels), all heat treatment methods (steel hardened and tempered on the running of the surface) have been employed in order to meet the requirements of the companies.

As we have shewn above, the 13 % manganese steel solved at one stroke the majority of the problems raised by the


– MATERIEL DE VOIE UNIFIE U.V.F. –
– AIGUILLAGE A DROITE –
– VOIE DE 1m44 –
– ELEVATION DE LA LAME –

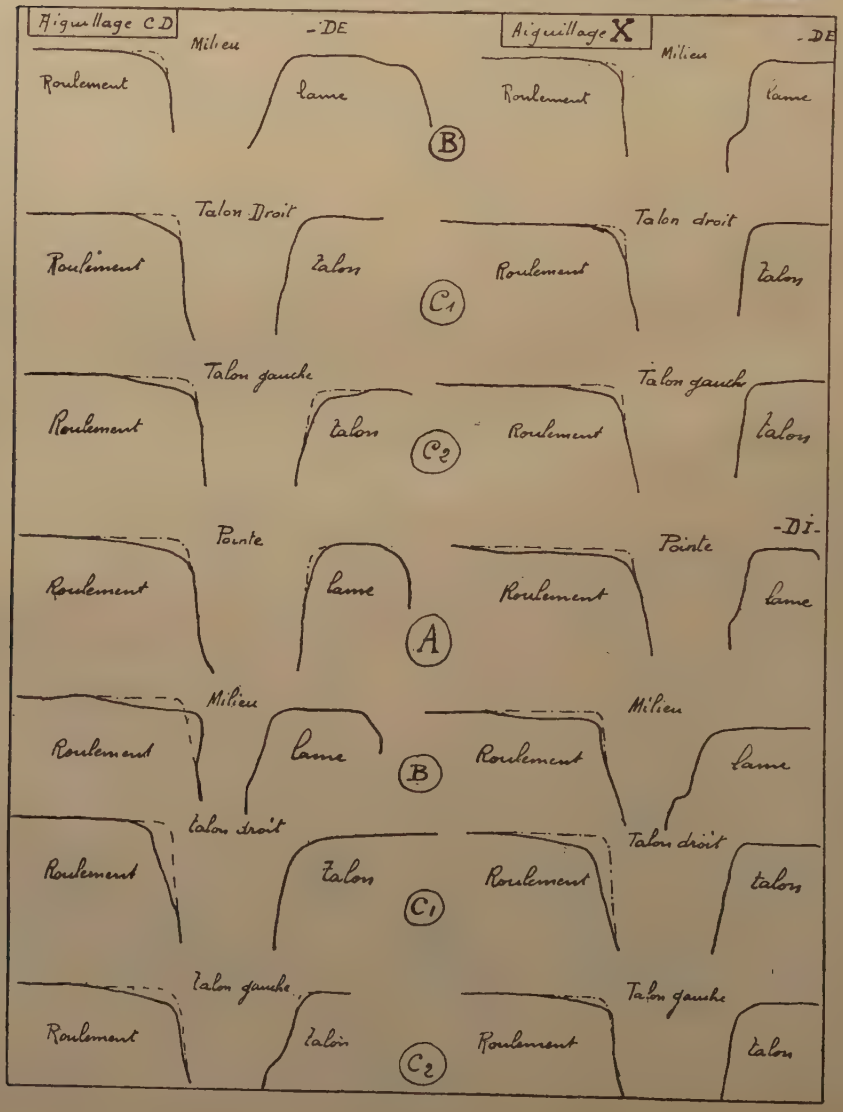

Aiguillage CD
-DE
Milieu
Roulement
lame
B
Talon Droit
Talon
C1
Talon gauche
C2
Pointe
A
Aiguillage X
-DI-

Fig. 4.

Explanation of French terms in figure 4 on opposite page :

Top : Matériel de voie unifié U. V. F. = U. V. F. Standard track. — Aiguillage à droite, rayon de 30 m. 00 sur l'axe = Right hand points of 30 m. (98 ft. 5 1/8 in.) radius with the centre. — Voie de 1m44 = (1.44 m. [4 ft. 8 3/4 in.]) track. — Plan de la boite d'aiguille, rayon extérieur = Plan of the point box, outer radius. — Élévation de la lame = Elevation of the point blade. — Plan de la lame = Plan of the point blade. — Plan de la boite d'aiguille, rayon intérieur = Plan of the point box, inner radius.

Bottom : Aiguillage = Point. — Lame = Blade.— Milieu = Centre. — Pointe = Point. — Roulement = Running surface. — Talon = Heel. — Talon droit = Right heel. — Talon gauche = Left heel.

Fig. 5. — The effect of inclusions on the wear.
Magnification = 150.

users and has rendered them the greatest service at a period when the traffic was becoming more intense as the exigencies of modern times increased.

The characteristics of this steel are in many ways remarkable and sensibly exceed the requirements of the usual specifications, thus it is usual to obtain from a forged test piece :

Strength . . . R $\geqslant$ 90 kgr. (57.15 English tons per square inch).
Elastic limit. E $\geqslant$ 35 kgr. (22.23 tons per square inch).
Elongation . A $\geqslant$ 30 %

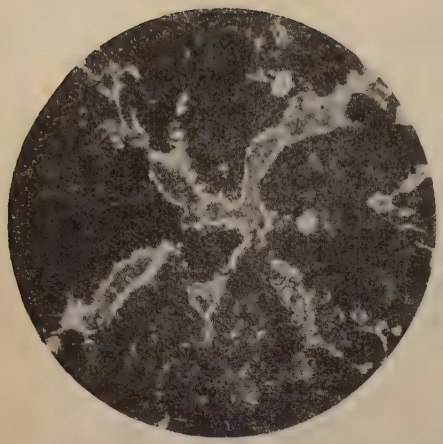


Fig. 6. — Inclusion of chrome.
Magnification = 150.

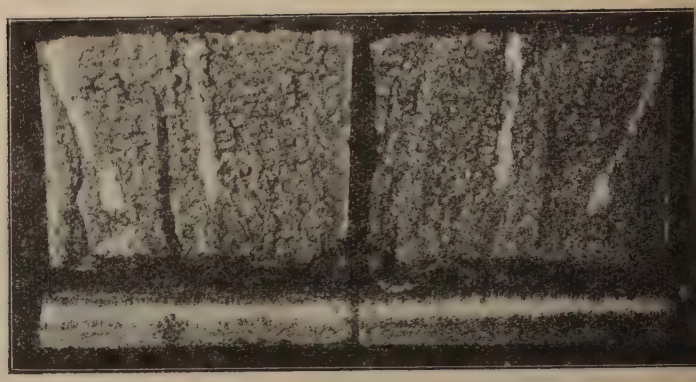


Fig. 7. — Absence of isotropy.
Magnification = 4.

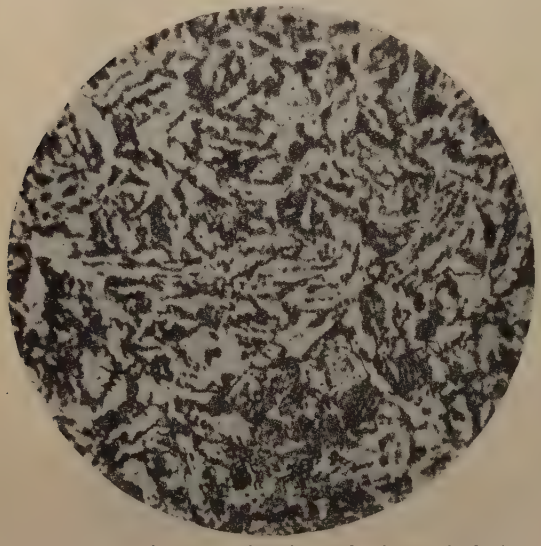


Fig. 8. — Nickel-chrome electric steel without inclusions.
Magnification = 1 000.

Fig. 9. — Nickel-chrome converter steel with inclusions.
Magnification = 1 000.

work hardening furthermore bringing the Brinell hardness of this metal above 130 kgr.

We all know the remarkable life of the first completed crossings delivered, the characteristics of the steel in which were :

Strength . . . R 110 to 120 kgr. (69.85 to 76.20 tons per square inch).
Elastic limit. E $\geqslant$ 50 kgr. (31.75 tons per square inch).
Elongation . A $\geqslant$ 50 %.
Resilience. . ρ $\geqslant$ 25 Kg.-M. (181 foot-pounds).

The metal was well mixed, homogeneous and free from inclusions, and

Fig. 10. — Nickel-chrome electric cast.

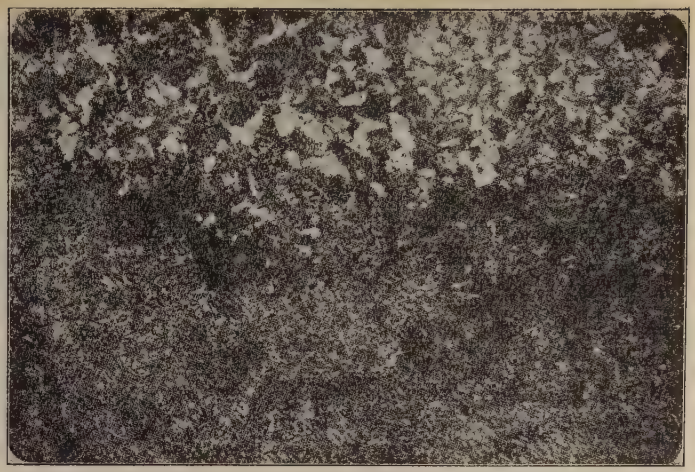


Fig. 11. — Special nickel-chrome steel.

Intercalary. Magnification = 150. Intercalary.

Fig. 12. — Nickel-chrome electric cast.

Fig. 13. — Nickel-chrome electric cast.

Figs. 10 to 13. — Welds of special nickel-chrome steel.

Figs. 14 to 18. — Nickel-chrome electric cast steel.

Fig. 14.

Explanation of French terms : Températures = Temperatures. — Coulée n° 49 = Cast No. 49.
Courbe dilatométrique etc... = Extension curve obtained on the Chevenard instrument.

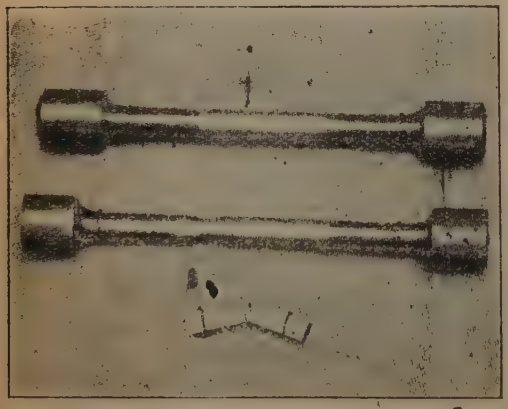


Fig. 15. — Test piece before and after tensile test.
Resilience test piece.

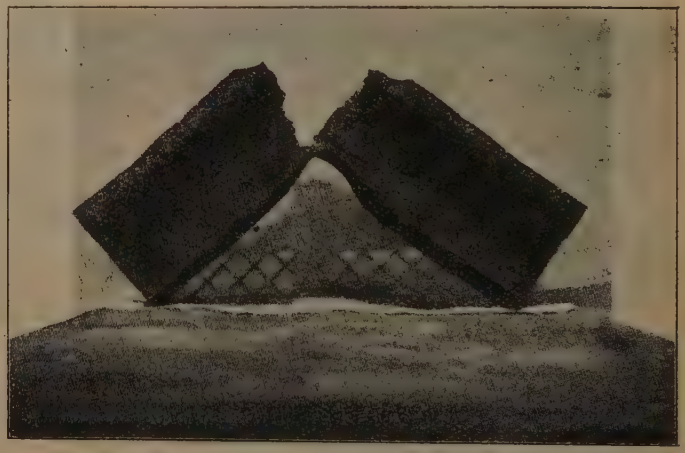
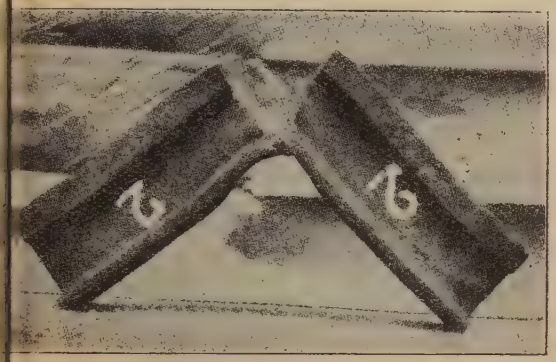


Fig. 16. — U. V. F. 1. notched rail having received a blow from a weight of 200 kgr. (660 lb.) falling 11 m. (36 ft. 1 in.).

Figs. 14 to 18 (*continued*). — Nickel-chrome electric cast steel.



g. 17. — Vignoles rail after blows of 300 kgr. (660 lb.) alling 14.5 m. (47 ft. 7 in.) and 1 000 kgr. (2 200 lb.) falling 8 m. (26 ft. 3 in.)

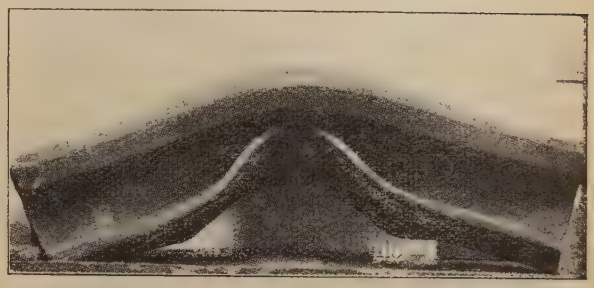


Fig. 18. — Vignoles rail having received 10 blows of 300 kgr. (660 lb.) from 6 m. (19 ft. 8 1/4 in.) and 3 blows of 300 kgr. (660 lb.) from 14.5 m. (47 ft. 7 in.).

could be work hardened to a Brinell hardness of 200 kgr.

We have therefore every reason to be satisfied with a metal the results of which has been approved by service, seeing that manganese steel points or crossings laid seventeen years ago are still in use.

The French and foreign Steel Works which have succeeded in perfecting this quality of steel deserve much credit, as no specialist is ignorant of the real difficulties of melting, of casting, and of pouring which they came up against and which they had to solve in order to provide the large tonnage needed for the subsequent development in use of this steel.

If the results obtained from the metal have in some cases varied, it should not be concluded that the quality has been wrongly chosen, but that it has been badly made as a result of a conjugation of incidental factors the investigation into which would take us too far afield.

It is none the less unfortunately true that manganese steel has a certain number of drawbacks which the users have unfortunately found as their experience of it increased, and the effects of which it has not yet been possible to combat.

Amongst these disadvantages or drawbacks, we will quote the impossibility of welding and building up, the difficulty of machining economically making it necessary to use the flame or high speed saws to cut it, thereby detrimentally affecting the quality, its mechanical properties and the metallographical texture in the as delivered state.

Local and accidental heating, such as that resulting from slipping, has also the same unfavourable influence.

It is rather frequently the case that manganese steel being on the soft side has a low elastic limit and Brinell hardness before becoming work-hardened, all which render it susceptible to crushing and hammering under shock, especially on the bearing surfaces of the blade of the point and at the joint.

This phenomenon accentuates in a progressive degree the defects of a joint, always a difficulty in itself, and the repeated shocks on the rolling stock : it then becomes necessary to overcome this by relevelling the track.

In spite of these drawbacks, the 13 %

manganese steel offers such great resistance to wear that at first sight it appears unnecessary to look for an ordinary cast steel of constant structure after reheating, within the range of machinable and weldable steels for automobile construction, and improved, if possible, in order to make it superior to rolled carbon steel.

Some tests on a small scale of manganese-silicon steel for tram lines in mines, chrome-nickel steel for pinions and gear wheels working under very different conditions, of 3 % nickel and 2 % chrome steels, on the Paris lines have, however, been encouraging.

The results, although good, would not have been followed up had it not been known that the Americans with their usual courage had been testing chrome-nickel steel on the Milwaukee tramways since 1919, although the characteristics of the metal they used were quite ordinary and made the results reported by Mr. Hibbard in the *Electric Railway Journal* of the 17 March 1923 the more remarkable.

In 1922, the Paris Tramways Company (S. T. C. R. P.) called the attention of the Gennevilliers Steel Company to the value the introduction of this material would have as regards French tramways, and assisted them in developing suitable steels by making many tests of converter steel (the only method of melting the Steel Works possessed at the time).

The first difficulty likely to be come up against in looking for a very hard weldable and machinable chrome-nickel steel is rather commercial than technical, owing to the costs of the additions to the molten metal, and to the working up and treatment needed : fortunately, the cost of the metal only represents 40 % of the total cost of the points and crossing, the other 60 % representing laying, paving, relevelling, anchoring the joint, lifting up, etc.

The range of steels that can be tried in substitution for manganese steel is fairly wide, but the necessity of being able to weld it directs the investigation in the direction *of treated steels* which resist wear through rubbing.

II.

Chrome-nickel cast steel for points and crossings material.

Laboratory results.

The method of working up the metal in the converter produced a good wearing steel but the user accustomed to 13 % manganese steel employed methods of handling the rails which the chrome-nickel converter steel would not stand owing to its great brittleness. This steel was replaced by the steel manufactured in the electric furnace with a view to getting a particularly compact and homogeneous steel similar to crucible steel with great strength under shock.

By the composition, the manufacture, care in casting and heat treatment, all in conjunction with one another, a steel of suitable instantaneous characteristics standing up well under repeated stresses has been produced.

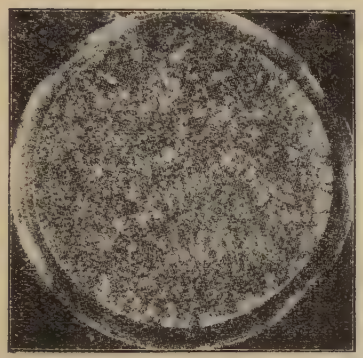
The characteristics are shewn in the normal tensile curve (fig. 2) obtained from a *cast test piece not forged* which gave a fibrous fracture with an almost complete cup of clear cut contours (figs. 14 to 18).

This type of test piece gave the following results :

Tensile	R	80 to 120 kgr. (50.80 to 76.20 English tons per square inch.)
Elastic limit . . .	E	60 to 105 kgr. (38.10 to 66.70 tons per square inch).
Elongation	A	15 to 7 %
Reduction of area.	Σ	45 to 20 %
Resilience	ρ	12 to 5 Kg.-M. (86.8 to 36.2 foot-pounds)
Brinell hardness .	Δ	230 to 350

Compactness and endurance under repeated shocks.

Ordinary rolled Thomas rail.



Magnification = 4.

Nickel-chrome electric cast.

Fig. 19. — Fatigue break after 6 079 blows of a 2.3 kgr. (5.06 lb.) hammer from 4 cm. (1 9/16 inches), 1 blow per second.

Fig. 20. — Fatigue break after 33 300 blows of a 2.3 kgr. (5.06 lb.) hammer from 4 cm. (1 9/16 inches), 1 blow per second.

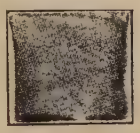
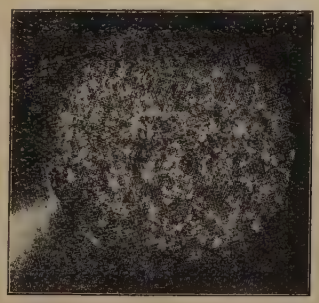


Fig. 21. — Test piece of 30 (1 3/16 inches) ⌀ having stood 25 blows from a 50 kgr. (110 lb.) tup falling 3 m. (9 ft. 10 1/8 in.) (test piece turned over every second blow).

Endurance under alternating rotative bending.

Ordinary rolled Thomas rail.



Magnification = 4.

Nickel-chrome electric cast.

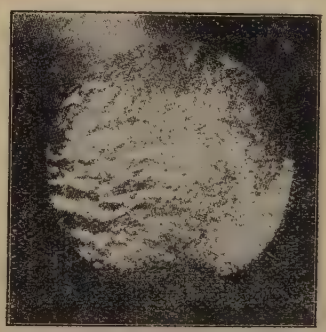


Fig. 22.

Fig. 23.

Fatigue fractures

after 5.149×10^6 alternations at 35 kgr. per mm² (22.23 tons per square inch).

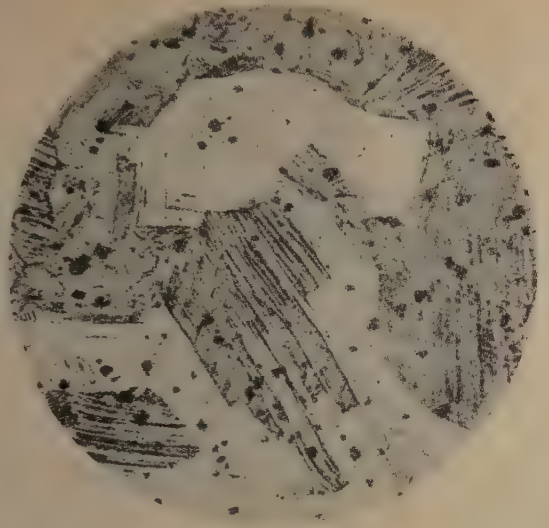
after 25×10^6 alternations at 35 kgr. per mm² (22.23 tons per square inch) and at 40 kgr. (25.40 tons per square inch) afterwards.

Test piece loaded at one end and turning on its axis at the rate of 1 800 revolutions per minute.

Figs. 19 to 23.

Fig. 24 to 29. — Comparison of the textures of manganese and nickel-chrome electric cast steels.

Manganese steel.



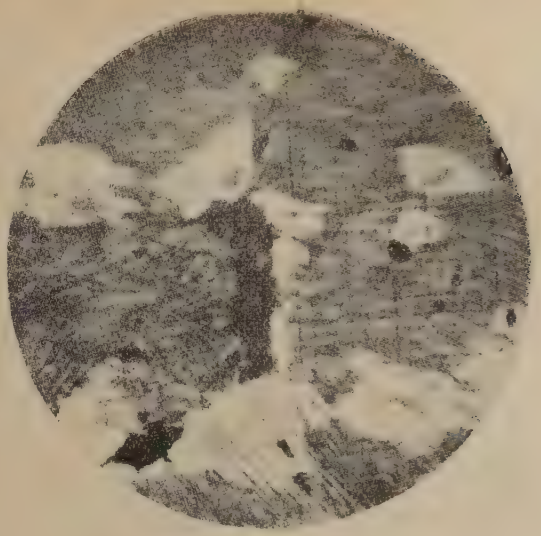
Converter-cast.

Fig. 24.

Magnification = 150

Heat treated condition.

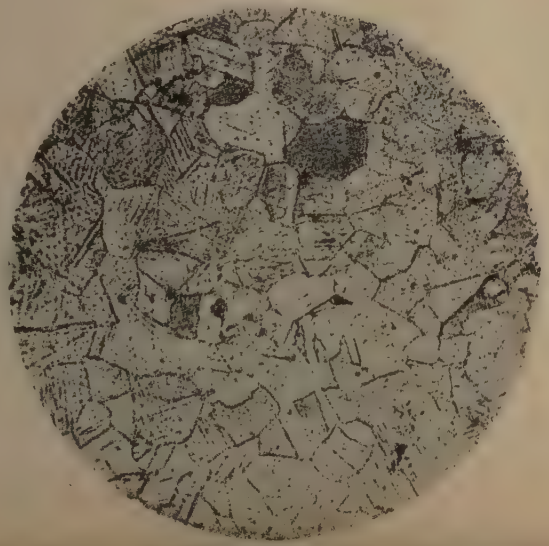
Manganese steel.



Converter-cast.

Fig. 25.

Manganese steel.



Electric-cast.

Fig. 26.

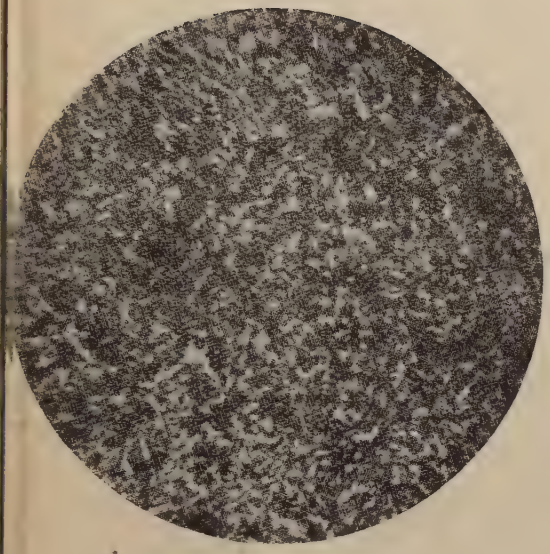
Magnification = 150

Heat treated condition.

Nickel-chrome steel.

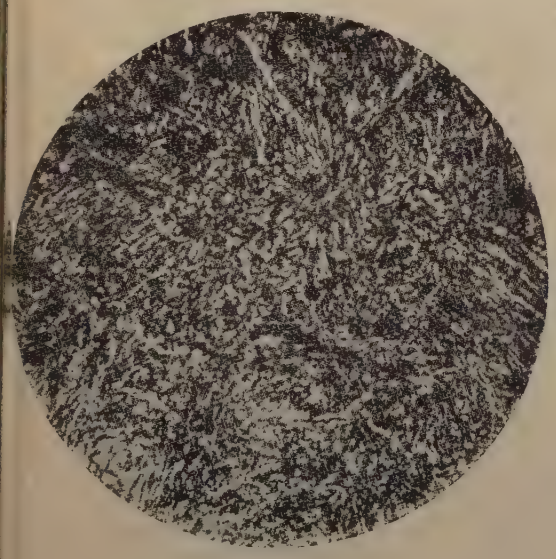
Electric-cast.

Fig. 27.



Electric-cast.
Fig. 29.

Magnification = 100
Heat treated condition.



Electric-cast.
Fig. 28.

the above figures being divided amongst several qualities of steel to suit permanent way requirements.

The very high elastic limit exceeding 75 % of the tensile strength should enable the metal to resist the first stresses due to hammering and to grinding away under shocks or blows, without preliminary hardening and exceptional elongation being needed.

In addition, the ratio between the elongation over the part reduced in area to the total elongation is fairly high, which should lead us to expect it to stand considerable deformation to which it would offer great resistance.

We have seen above that the Americans have put on the Market a nickel-chrome steel which has given good results : this steel had insufficient Brinell hardness in our opinion; we therefore raised this hardness whilst maintaining or improving the other characteristics, the elastic limit of elongation, the reduction of area, and the resilience.

As regards the mechanical characteristics, we also tried to make electric chrome-nickel cast steel of equal quality to forged and rolled chrome-nickel steel of the same grade, melted with great care and used for parts subjected to rubbing working to a very rigid specification. It should be remembered in connection with this matter that between the cast steel that has undergone no forging work to improve the grain, and rolled steel in which the grain is broken up and of which the characteristics are determined lengthwise, there can be a great difference.

With *cast* steel, no forging can be done, to get sufficient closeness of grain, and if the steel is badly melted, it is impossible to restore it by simply heat treating it, if also the cast steel is not *isotropous,* we shall get poorer characteristics as they are not brought into line and improved by rolling : to be exact a cast steel should be compared not with a rolled steel tested *lengthwise,* but with a rolled

steel tested at 45° *to the longitudinal and transverse axes.*

It is of course very unusual for a steel maker to guarantee the characteristics if taken *across the direction of rolling of the steel.*

Only very rigidly controlled methods of making the steel will make it possible to get a steel sufficiently fine grained to be comparable with rolled steel tested in the direction of rolling.

The resilience or resistance to shock is much greater than that of the usual Thomas rail for a hardness above 20 kgr. the metal therefore can be used with complete safety on the track even in the case of local heating or cooling during some time as the curve of figure 3 shews (this is not so with some hard carbon steels, and with Thomas rail steel in particular, the very low resistance of Thomas rails against shock in winter being well known).

The changes in the resilience shewn are the maxima noted : it should be noted also that two cast test pieces for the resilience test are never exactly the same within 1 Kg.-M. (7.23 foot pounds) the points — 12° and + 450° (10.4 and 842° F.) are therefore simply marked by a very small drop in the resilience without it being possible to certify that this drop really occurs.

The investigation of the strength of the metal under repeated stresses was also the subject of a series of tests over a considerable period. We adopted for this investigation stresses similar in kind and frequency to those to which the metal is subjected in the track (shocks and rotary bending).

In the various cases of stress, whether alternating or not, the electric chrome-nickel cast steel has shewn itself equal or even superior to all rolled or cast steels usually used in the track, of the same strength. It has demonstrated its equality or superiority to all steels of the same composition carefully melted and rolled (figs. 19 to 23).

In certain instances also, the difference has been the proportion of 1 to 10 with the Thomas steel generally used.

A test of 227 hours has shewn that the fatigue stress of this electric chrome-nickel cast steel exceeded 35 kgr. (22.23 tons per square inch). The thermic welding of chrome-nickel steel on chrome-nickel steel investigated under the same conditions has given results at least as good as with fine grained rail steel and sometimes distinctly better.

We were quite naturally led on to compare these results by their metallographical textures : the close grain and absence of inclusions clearly shewed a metal free from hysteresis which tended towards the perfectly elastic form, capable of absorbing a great amount of intermolecular energy before its grain would be broken or fissured by repeated stresses (figs. 24 to 29).

The disappearance of the initial grain (not marked by non-ferrous inclusions) is complete, and consequently we hope that a scaling off of the work hardened running surface is not to be feared any more than wear by flaking.

It is moreover certain that all methods of melting will not produce identical results, for any particular grade of steel chosen.

This metallographical structure, furthermore, is comparable in every way with that of the rolled steels used in automobile and aeronautical construction which become closer grained and also polished under prolonged frictional rubbing, it is stable at all temperatures below 750° C. (1 382° F.) which may result from a localised heat such as that caused by slipping (figs. 30 to 35).

A comparative series of tests given below shew what can be expected from chrome-nickel electric cast steel as regards hot bending and resistivity.

Hot bending of chrome nickel electric cast steel.

25 mm. (63/64 inches) square. — 50-ton Amsler machine.

At 0° C. (32° F) : $\hat{\alpha} = 132°$ ... appearance of first crack.

At 450° C.(842° F) : $\alpha = 180°$ ..... bent solid without crack.

Resistivity in microhms-square cm. per cm. at 18° C. (64.4° F.) of the cast chrome nickel electric steel.

Chrome-nickel electric cast steel	28.6
Rolled Thomas steel	26.2

III

Use of chrome-nickel cast steel in points and crossings.

Results in practice.

We give below a resumé of the results reported by Mr. Hibbard with regard to the chrome-nickel cast steel used on the Milwaukee Tramways.

—	Total wear.	Number of vehicles per millimetre (0.039 inch) of wear.
1 year's service.	Millimetres. (Inches).	
Manganese steel	4.76 (0.187)	40 000
Chrome-nickel steel . . .	1.58 (0.062)	121 000
2 year's service.		
Manganese steel	9.52 (0.374)	105 000
Chrome-nickel steel . . .	4.76 (0.187)	175 000

The results given by chrome-nickel steel made at the Gennevilliers Steel Works can certainly not be taken as conclusive : they were, however, very creditable, as will be seen by the comparison between two pairs of points given in appendix II (fig. 4).

The points in electric *chrome-nickel cast steel* were put into service quite recently : it will be understood therefore that a review of the results cannot yet be given.

These points of standard dimensions for each type can furthermore be supplied without any danger of brittleness in several different Brinell hardness conditions.

The practical shock tests on 30 mm. (1 3/16 inches) square bars and on rails tested with 300 to 1 000 kgr. (660 to 2 200 lb.) tups gave very satisfactory results as table A, appendix III, shews.

It should be noted that the drop was fairly high before fracture occurred.

Straightening cold under the press gives the users every guarantee of safety in view of the high elastic limit of the metal which makes this work a rather delicate operation.

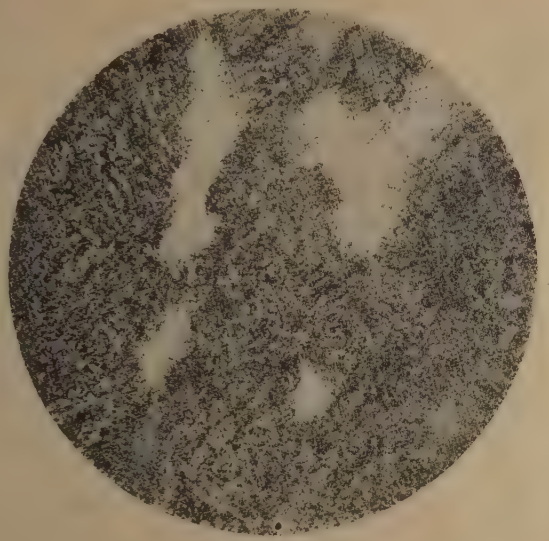
Appendix III, table B, gives some results of cold bend tests on U. V. F 1 rails in electric chrome-nickel cast steel.

The thermic welding of these chrome-nickel steels together and to rails can be done with the required degree of safety : by means of suitably chosen welding rods and suitable heat treatment, it has been possible to reduce to less than 15 kgr. the difference in Brinell hardness between any two neighbouring points close to the weld without sensible diminution of the elastic limit, the elongations and the reductions in

Fig. 30 to 35. — Comparison between nickel-chrome electric steel cast and rolled.

Nickel-chrome cast.

Magnification = 150.



As cast

Fig. 30.

Magnification = 1 000.

Heat treated without tempering.

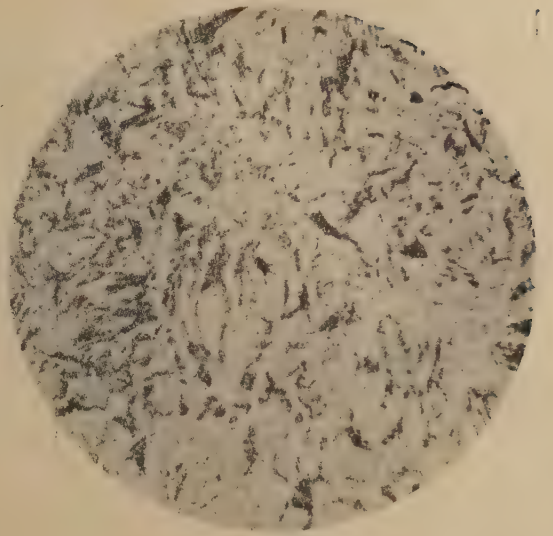
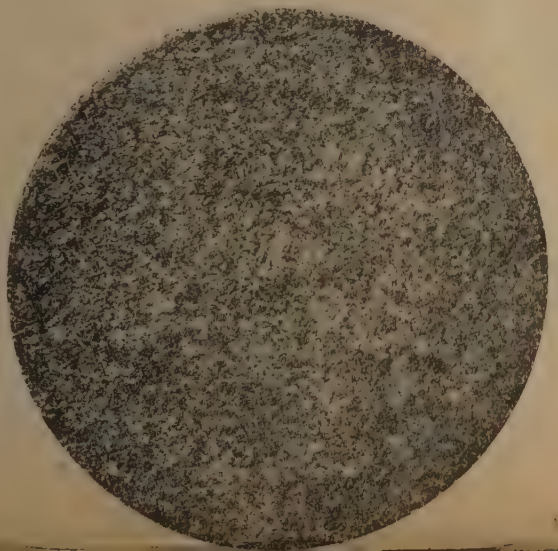
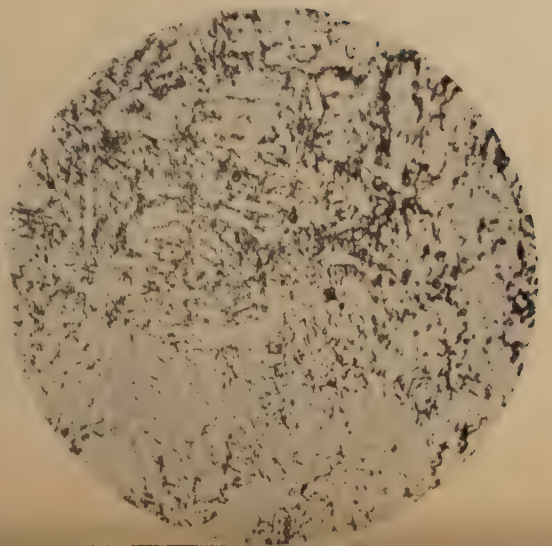


Fig. 31.



Treated.

Treated.



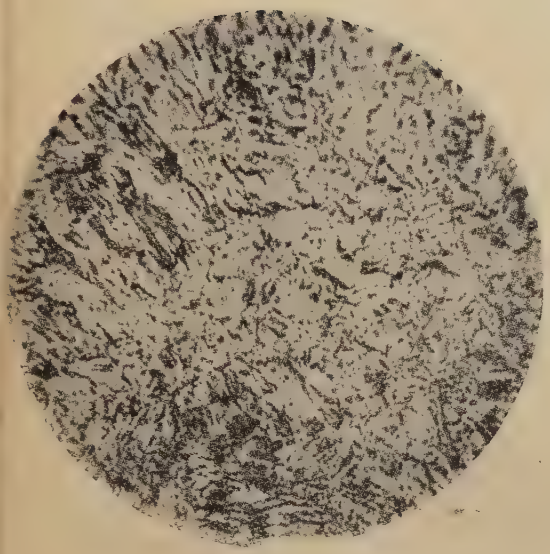


Fig. 35. Treated.

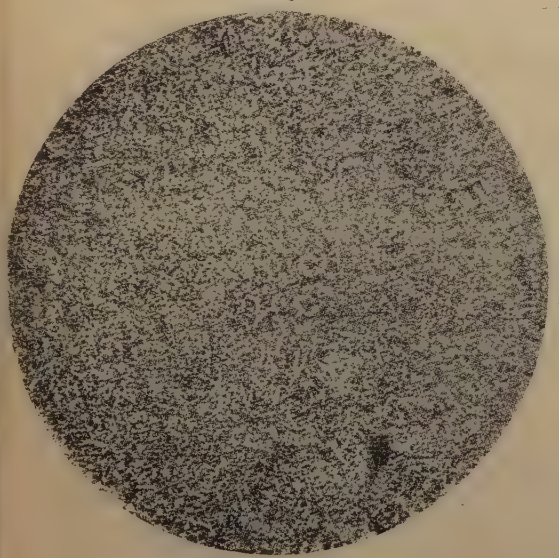


Fig. 34. Treated.

area on a test piece cut out across the weld (figs. 10 to 13).

Welding and building up by electric welding are also possible.

As regards machining, the hard grade, which is also the most resisting to abrasion, can be machined quite easily up to a hardness of 120 kgr.

To sum up briefly, it can be said that French chrome-nickel converter steel has stood up most creditably to hammering and to general wear during the last five years, and that American chrome-nickel steel, of which the method of manufacture is unknown to us, has given excellent results since 1919; based on the above considered factors, it seems to us to be incontestable that an *electric chrome-nickel cast steel* which undoubtedly represents the high water mark of manufacture should result in considerable improvement in all cases in which wear is combined with repeated shocks.

It must not be concluded too quickly that electric chrome-nickel steel will be the universal cure for all the problems met with. If we consider points and crossings alone, this metal represents the beginning of a very real progress. It revealed certain weaknesses which research work will make good. So far, five years practical service led us to expect that the result will be helpful, but in permanent way work a few more years must pass before we can possess an opinion founded on fact.

We can be persuaded in any event that it is in the investigation into the method of working up the metal in conjunction with the metallographical texture, and subsequently with the molecular structure, that the key will be found to the various enigmas that are encountered at every step when investigating the phenomena of wear and of work hardening.

APPENDIX I.

Definitions relative to the characteristics of steels.

Tensile strength.

The tensile strength is defined by the maximum value of the load producing the fracture of a test piece subjected to tension : it is expressed in kilogrammes per square millimetre of the *original* section.

Real tensile strength.

The real tensile strength is defined by the value of the load at the moment of fracture of a test piece subjected to tensile stress : it is expressed in kilogrammes per square millimetre of the *final* section.

Elongation.

The elongation is defined by the increase in length between gauge points of a test piece broken in tension : the figure obtained may vary with the form and the length of the test piece, especially with metals shewing much reduction in area.

There are three kinds of elongation at ordinary temperatures : elastic elongation, distributed elongation, and localised elongation at the zone of reducing area.

The phenomenon is more complicated at high temperature when viscosity enters into play.

Elastic limit.

The elastic limit is defined by the load in kilogrammes per square millimetre of the original section at which the elongations cease to be proportional to the loads or by the load in kilogrammes per square millimetre of the original section at which there remains an appreciable permanent elongation after this load is removed without there being absolute correlation owing to the phenomenon of hysteresis defined further on.

Elastic elongation.

The elastic elongation is defined by the maximum value of the elongation that a metal subjected to tensile stress is capable of supporting before attaining the point of permanent deformation.

Striction.

The striction is defined by the reduction of section a test piece undergoes under tensile test.

Brinell hardness.

The Brinell hardness is defined by the ratio of the pressure in kilogrammes to the area of the impression in square millimetres of a ball of given diameter pressed into the metal being investigated.

Ductility.

The ductility is the property a metal possesses which enables it to be drawn down into wire.

Resilience.

The resilience is defined by the work in kilogramme-metres absorbed by the sudden breaking of a notched test bar.

This definition does not meet the case as the work done in breaking the bar depends above all upon the volume deformed, whereas the co-efficient of resilience relates to the work at a section : in any case, the breakage by shock has no relation to the breakage under tensile load steadily increased.

Work done at fracture.

The work absorbed at fracture is defined by the diagram of the tensile test curve : it is in fact the work expended in order to break a tensile test piece.

Hysteresis.

The hysteresis can be defined as follows :

If we represent by a curve the deformation of a steel as a function of the load F to which it is subjected in the two directions (O to F) and (F to O), we obtain a return curve which as a rule does not lie superimposed upon the outwards curve, except in the extreme case of deformation of a perfectly elastic steel: we are then said to have hysteresis.

The diagram obtained, in every way analogous to a diagram of magnetisation, corresponds to a dissipation of energy.

Decrement.

The phenomenon of hysteresis is usually illustrated by test in a spring torsion oscillating machine which gives oscillations damped out by the *internal friction* of the spring; this internal friction is characterised by the relative distance between two successive elongations, which is called decrement.

Work hardening.

Work hardening is correctly defined as being a phenomenon which has more or less modified the material of the non-plastic body as a result of permanent deformations having broken down its continuity : the increase in hardness when it happens to occur would then be only the consequence of this phenomenon.

In our opinion, setting aside a rearrangement and redistribution of carbon, work hardening rarely alters the metallographical texture of a steel except in the case of a manganese steel, and it can be admitted that the closest grained and most homogeneous texture is also the most work hardened.

Isotropy.

Isotropy can be defined by the identity of the mechanical characteristics obtained from test pieces cut out in all directions round a given point.

Cross grained.

A metal is said to be cross grained when its mechanical characteristics in the direction of rolling are clearly different from those at right angles thereto, the inclusions and grains of the first consolidation being clearly locateable.

APPENDIX II.

—	Point C. D.	Point X.
Steel	Nickel-chrome.	Manganese.
Date laid	27 April 1925.	6 may 1925.
Date wear measured	15 February 1927.	15 February 1927.
Length of service	About 22 months.	About 22 months.
Points run through from the	Heel.	Heel.
Number of times run through daily.	415.	50.
Equal to	6 640 tons.	800 tons.
Total number of times passing over.	274 000 approx.	32 500 approx.
Equal to	4 400 000 tons approx.	520 000 tons approx.
Wear was in the ratio of.	1 to 5 approx.	

APPENDIX III.

Table A.

Electric chrome-nickel steel, cast and heat treated.	
On square bar 30 mm. (1 3/16 inches) side — 160 mm. (6 5/16 inches) between supports. Tup of 50 kgr. (110 lb.) falling 3 m. (9 ft. 10 in.).	On U. V. F. 1 rails or Vignoles 500 mm. (1 ft. 7 11/16 in.) between supports. 300 and 1 000 kgr. (660 and 2 200 lb.), tup varying height of fall.
R = 93 kgr. (59.05 English tons per square inch) — 12 to 25 blows before fracture (test piece turned every second blow).	R = 80/85 kgr. (50.80 to 53.97 tons per sq. inch) — U. V. F. 1 rail [notched] 300 kgr. (660 lb.). Intact up to 9 m. (29 ft. 6 in.) after several blows at 4 m. (13 ft. 1 1/2 in.), 6 m. (19 ft. 8 1/4 in.), 7 m. (22 ft. 11 1/2 in.). At 11 m. (36 ft. 1 in.) open not broken-deflection 220 mm. (8 11/16 inches) — opening 160 mm. (6 5/16 inches).
(R = 80 kgr. (50.80 English tons per square inch) — for comparative purposes, the chrome-nickel steel cast from the *converter* stood one blow.)	R = 80/85 kgr. (50.80 to 53.97 tons per sq. inch.) — Vignoles rail 51 kgr. per metre (102.81 lb. per yard) [not notched] 300 to 1 000 kgr. (660 to 2 200 lb.) tup. At 300 kgr. (660 lb.) intact up to 14.5 m. (47 ft. 7 in.) after several blows at 6 m. (19 ft. 8 1/4 in.), 8 m. (26 ft. 3 in.), 10 m. (32 ft. 9 3/4 in.), 12 m. (39 ft. 4 1/2 in.). At 1 000 kgr. open not broken at 4 m. (13 ft. 1 1/2 in.) deflection 204 mm. (8 1/32 inches) — opening 30 mm. (1 3/16 inches).
	R = 80/85 kgr. (50.80 to 53.97 tons per sq. inch). — Vignoles rail 51 kgr. per metre (102.81 lb. per yard) [not notched] 300 to 1 000 kgr. (660 to 2 200 lb.). At 300 kgr. (660 lb.) intact up to 14.5 m. (47 ft. 7 in.). At 1 000 kgr. (2 200 lb.) broken at 8 m. (26 ft. 3 in.) after one blow at 4 m. (13 ft. 1 1/2 in.). (Deflection 205 mm. (8 1/16 inches) — opening 133 mm. (5 1/4 inches) (see figs. 14 to 18).

Table B.

Cold bend test on nickel-chrome electric cast steel.

Rail U. V. F. 1. — Length : 1.7 m. (5 ft. 7 in.)

Distance between the rollers when making the test : 0.5 m. (1 ft. 7 11/16 in.).

Deflections of 19 mm. (3/4 inch), 25 mm. (1 inch), and 28 mm. (1 3/16 in.) corresponding to radii of 25 m. (82 ft. 1/4 in.), 17 m. (55 ft. 9 1/4 in.) and 15 m. (49 ft. 2 1/2 in.) respectively, have been obtained without cracks, on a length of 1 m. (3 ft. 3 3/8 in.). — A deflection of 40 mm. (1 9/16 inches) corresponding to a radius of less than 10 m. (32 ft. 9 3/4 in.) did not increase a small foundry crack.

[625 .143.3 (.73) & 625 .245 (.73)]

Transverse fissures can now be located.

Figs. 1 to 7, pp. 255 to 261.

(*Railway Age.*)

On 25 August 1911, a passenger train on the Lehigh Valley was derailed near Manchester, N. Y., killing 29 passengers and injuring 62 others. The investigation of this accident showed that is was caused by the failure of a rail, which broke into 17 pieces. Examination of this rail brought to light a new type of failure, which has since come to be known as an internal transverse fissure. Following this accident similar failures have occurred on other roads, notably that on the St. Louis-San Francisco at Victoria. Miss., on 27 October 1925. Few roads have been immune, and while most of the failures have been without loss of life, the fact that they cannot be detected until collapse occurs makes them a constant menace, the magnitude of which it has been impossible to determine with any degree of certainty.

Because of the seriousness of this type of failure, railway engineers, rail manufacturers and government agencies have given a great deal of study to the problem since 1911, working more or less independently. Their results were largely contradictory and provocative of controversy. Until about two years ago there was little agreement among students of rail manufacture and service regarding the cause of these failures. About this time, however, the American Railway Engineering Association (A. R. E. A.), which is also the engineering division of the American Railway Association (A. R. A.), perfected an arrangement with Elmer A. Sperry, an outstanding scientist and electrical engineer, whereby he undertook the development of a machine for this Association, to detect and locate these fissures in rails as they lay in track. The success of this development has now been demonstrated, for, as related on a following page, the equipment that has been built has proved its ability to detect fissures to the satisfaction of the A. R. A., and has been accepted. It is now in daily service checking the condition of rails in important main tracks.

The development of this equipment constitutes an outstanding achievement in the transportation industry. By detecting the presence of fissures, it makes it possible to remove them from the track before failure occurs, thereby eliminating a menace to travel which gave promise of becoming exceedingly serious. Furthermore, by reason of the ability of this equipment to determine the relative size of fissures within rails, successive readings should indicate whether this form of failure is progressive and, if so, the rate of growth and the conditions promoting it. With such information, it should be possible to determine the cause of transverse fissures and also to develop the necessary measures for their elimination, which is, of course, the ultimate objective.

In the meantime, the operation of this car is being watched with intense interest because of the light that it is shed-

ding on the relative prevalence of transverse fissures. Some students of this subject have feared that this form of failure will be found to be so numerous as to require the immediate replacement of tremendous quantities of rails and the continued operation of trains only under serious hazard until new rails can be secured and laid. Others have estimated that the number of defective rails will be found to be as low as one per cent of the rails in track. While any conclusions based on a study of less than 200 miles of tracks may be subject to wide error, it is reassuring to note that the first results on this limited mileage showed defects in only 0.06 % of the rails examined. In other conditions, although each individual transverse fissure is cause for serious concern, first information indicates that their prevalence is far less than had been feared in many quarters.

After months of study, experiment and tests, the new Sperry transverse fissure detector car is now in actual service on certain lines in the East. This equipment not only searches out and records on a permanent paper record the location and relative size of all internal fractures in the heads of rails, but also marks the precise locations of such fractures directly on the rails themselves, by means of a paint spray.

General description.

This equipment, which is operated and controlled entirely by electricity, forms a complete, self-contained unit, compactly arranged on the platform of a heavy-duty trailer car and entirely enclosed against the elements by a frame housing fitted with windows on all four sides. When in operation, the entire unit is pulled over the track by a motor car at a speed of about five miles per hour and, under the observation and direction of two operators, functions entirely automatically .

The fundamental principle utilized in the new detector equipment is based upon the fact that if the rail is made to act as an electrical conductor and is saturated with a very heavy current, all internal hidden flaws encountered, including occlusions, shattered zones, pipes and fissures, present obstructions in the path of the heavy current forced through the rail. This is true even though the flaws are very small, and regardless of whether they are disposed horizontally, at an angle, or are truly transverse to the longitudinal axis of the rail. In other words, when the saturated current reaches any of these flaws or fissures, it cannot proceed in a straight line, and is, therefore, required to make an abrupt change in its direction in passing around the obstruction. In the new transverse fissure detector car, special apparatus has been developed, which is located in the region between the points where the heavy current enters the rail and leaves it, by means of which any deviation or abrupt change of direction of the current within the rail is detected immediately.

The principal units of the detector equipment for locating defects in rails consist of a gasoline engine-generator set, rail contact brushes carrying the energizing current to the rail, and a special device which passes along the top of the rail head, for detecting and measuring the abrupt current changes referred to above. As these changes in the direction of the current produce only a very feeble manifestation, this is carried to amplifiers, similar to those used in radio reception, which build it up to a point where it can be utilized for operating relays. The relays, in turn, control electric circuits of larger capacity, which operate all of the recording instruments.

The principal recording instrument of the detector equipment consists of a series of seven electrically-controlled recording pens which operate on a table, over which moves a continuous strip of

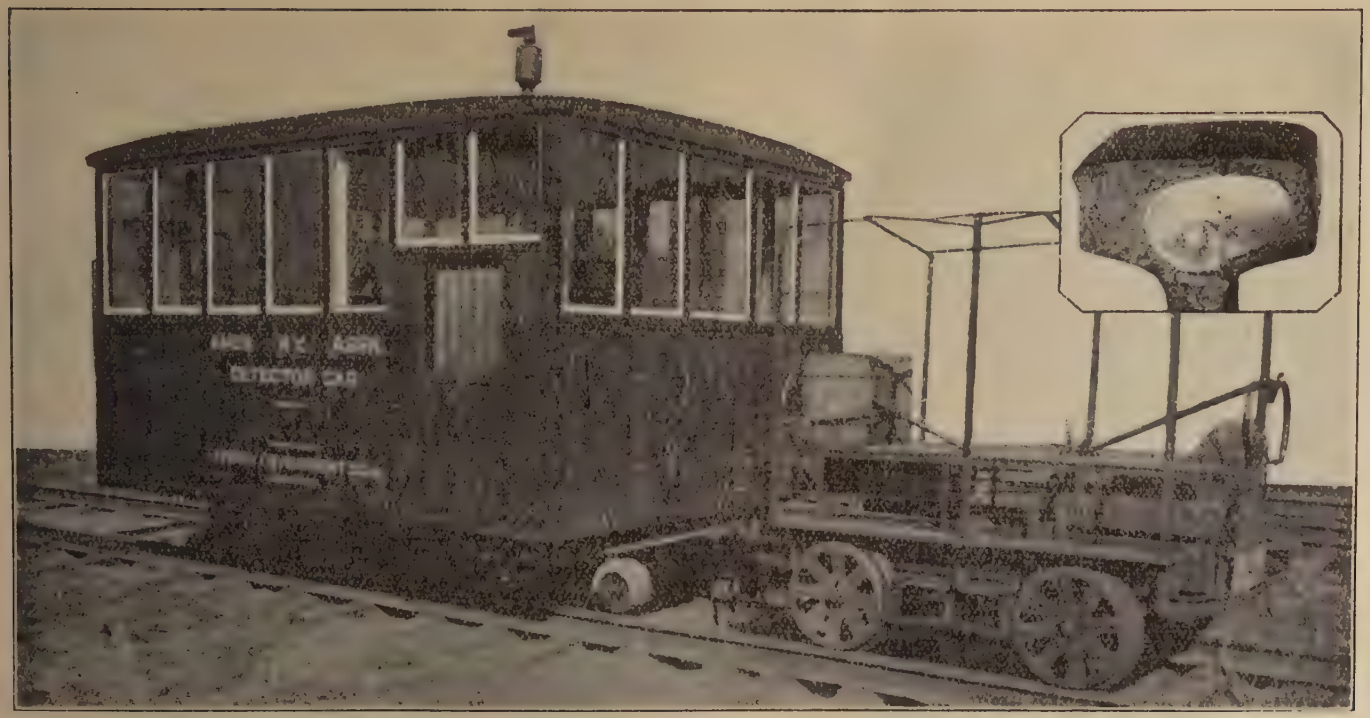


Fig. 1. — The new American Railway Association detector car as operated over the New York Central pulled by a heavy-duty moior car.

paper. Six of these pens are transverse fissure indicators—three for each line of rails, the seventh indicating the location of the joints in the track. Supplementing this paper record, a paint gun on each side of the car automatically sprays a spot of paint on the track rail, precisely at the point where the detector equipment indicates a defect of some character.

Early detector equipment developed defects.

During the 15 years immediately preceding the successful development of the present A. R. A. detector car, three principal methods, or principles, have been experimented with an effort to develop a satisfactory device for detecting transverse fissures. These were a mirror mounted on a special frame for movement along the rail, whereby visual inspection could be made of the under side of the rail head; the magnetic principle, wherein the rail was magnetized, and flux leakage, due to irregularities in the material, was detected by search coils; and the measurement of the resistance effect of discontinuities in the rail head by energizing the rail and then detecting the minute difference in potential resulting at transverse fissures. All of these methods, including the last, which was the principal upon which the Sperry detector equipment was first based, have been discarded. The mirror method was both slow and laborious and had the further serious objection that the detection of failures was impossible until development had reached the contour of the rail section, at which time the rail was practically ready to break. The magnetic apparatus proved highly sensitive and was discontinued as impractical because it produced results from which it was impossible to differentiate between transverse fissures and such other head irregularities as result from the slipping of drivers, gagging and cold bending of the rails, accidental spike maul blows on the rail, the cold rolling effect of wheels, segregation, laminations, etc.

After having given highly satisfactory results in extended laboratory experiments, the Sperry method of measuring the difference in potential caused by the presence of fissures in rails was also discarded soon after experiments were made under actual track conditions, in spite of the fact that the greatest optimism was felt for its success. On the whole, the equipment was found to be fundamentally correct and properly arranged, and the impractical factor was due, not to the method itself, but to the fact that the rails in track were found to be coated with a superimposed layer of hammered-in enamel, usually consisting of insulating ferro-ferric oxide some thousandths of an inch in thickness. The thickness of this layer of enamel seems to be in proportion to the density of traffic and, in some instances, where this layer is heavy, all of the cold forging of the rail by wheel action, to which the deformation of the rail is due, apparently goes on through the layer.

In an attempt to overcome the difficulty presented by this layer of insulating material, several types of cleaning brushes were experimented with, but in each instance with unsatisfactory results. The only method found by which it was possible to get down through this layer to the actual surface of the steel rail itself was through grinding. This process was effective but was found to be altogether too slow to be practical, and therefore, new research had to be instituded to overcome this serious difficulty. The seriousness of this difficulty was added to by the presence of rust, dirt, mill scale, and other irregularities commonly found on the surface of rail heads.

After several months of experimenting with this method of detection on a special test section of track on the New York Central, in which a considerable number of rails known to have trans-

Fig. 2. — A view from the rear of the car showing the relay and amplifier table, paint spray and meter panel.

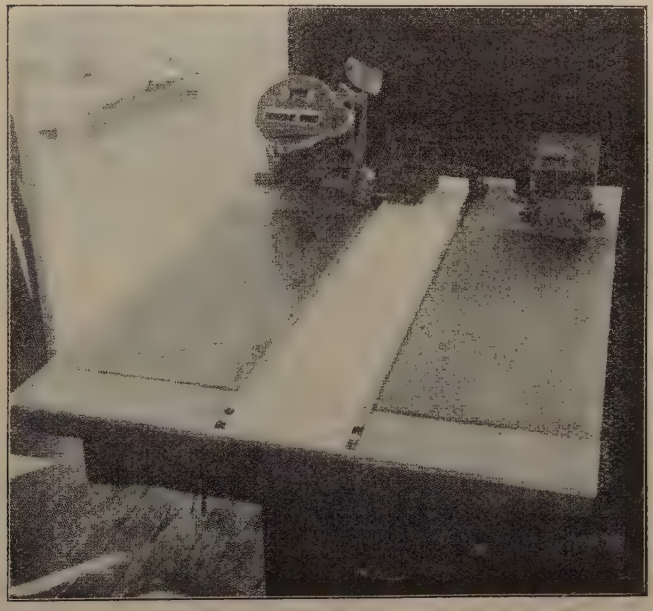


Fig. 3. — The recording table, showing its seven pen instrument, and the speedometer and joint counter.

verse fissures were laid, and also on the main line, the entire method then used to detect fissures was changed to the new method now employed. As a result, the present transverse fissure detector equipment differs in many respects from the equipment under test early in the year and described briefly in the 9 March 1928 issue of the *Railway Age*.

Description of electrical equipment and circuits.

The present equipment, which consists essentially of a gasoline engine-generator set, rail contact brushes, a pick-up device, amplifying tubes, a number of relays, a recording table with electrically-operated pens, a paint gun unit for marking the location of fissures, and rail cleaning brushes, is mounted on a standard steel-frame Kalamazoo trailer car equipped with four-wheel hand-operated brakes. Above the platform this car is enclosed in a special frame housing, the upper half of which is fitted with drop sash windows on all four sides. The car is equipped with a drawbar and, when in actual operation, is pulled over the track at the rate of about five miles per hour. Motive power for pulling the detector equipment on the New York Central was furnished by a Casey Jones motor car equipped with a Ford engine. On other lines, however, it is planned to pull the car by such suitable power as the roads can provide.

The power plant of the detector equipment is an engine-generator set consisting of a separately excited direct current generator with a rating of 4 000 amperes at 2 volts, operating at 900 revolutions per minute, which is direct- connected to a 25-H. P. water-cooled Waukesha, gas engine. The exciter unit, which is a diret current generator capable of developing 110 volts at 10 amperes, is belt-connected to the main drive shaft of the gas engine. This equipment is compactly arranged across the forward end of the car platform.

From the generator the current developed is carried through heavy copper conductors to bus bars on each side of the car, which, in turn, are connected by separate conductors to each of the rail contact brushes. In all, there are 32 such brushes, assembled in four groups of eight brushes each two such groups being located in line with each other on each rail and spaced about three feet apart. In each of these contact assemblies the brushes are arranged in four sets of two each, located directly behind each other, and are held in a rigid, brass, brush carriage. The brushes themselves are solid copper bars and have a mitered rail contact face so as to present a maximum contact surface to the rail. This is the main point of difference between the present type of brushes on the car and those used during the early experiments, the old type brushes having consisted of layers of wire gauze, compacted into more or less flexible bars. As was the case with the old brushes, the new type brushes are pressed against the head of the rail by heavy springs, forming a part of the brush carriages. The new type of brushes have been found better adapted to the service demanded and, being rigidly pressed against the rail, effect sufficient contact with the steel through the surface coating of insulating ferro-ferric oxide to transmit the current.

The weight of each brush assembly, when lowered to the rail, is carried by two flanged wheels, one at each end of the brush carriage. In addition, these wheels, which are held tightly against the gage side of the rails by springs, insure the accurate integrity of location of the whole electric system with respect to the rail.

Both brush carriages on each side of the car are hung from a suitable side beam and are raised and lowered simultaneously by the operation of a hand lever inside the car. When in the lowered position, the brush carriages are independent electrically and practically

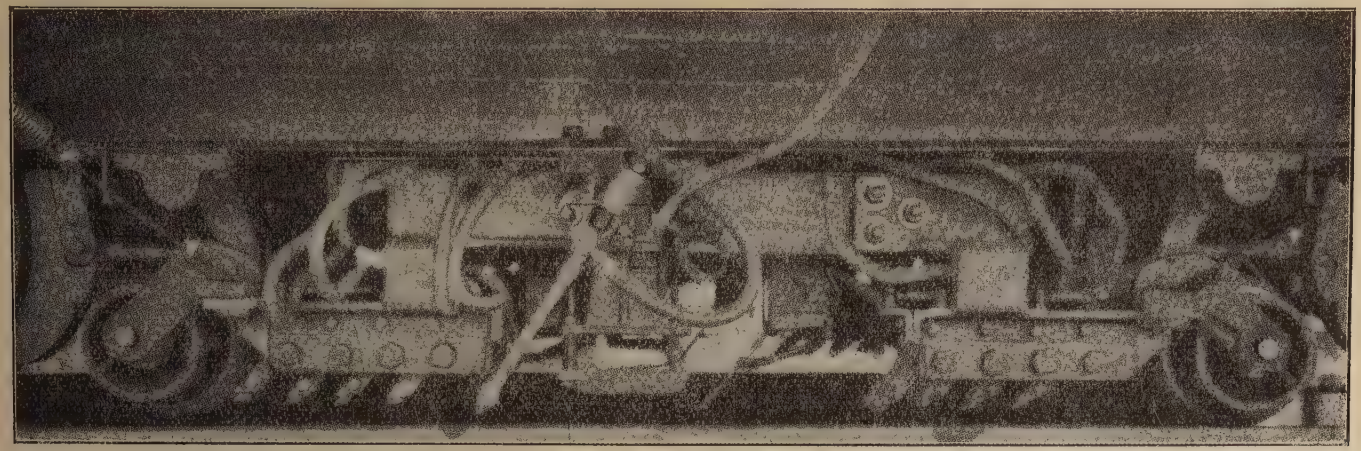


Fig. 4. — One pair of the brush carriages in the raised position, showing contact brushes, paint gun and pick-up device.

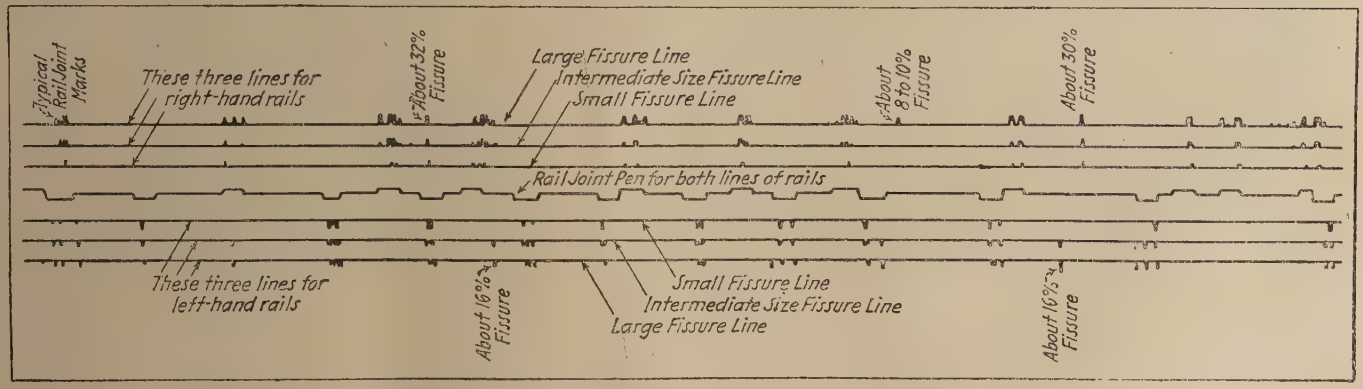

Typical Rail Joint Marks
These three lines for right-hand rails
About 32% Fissure
Large Fissure Line
Intermediate Size Fissure Line
Small Fissure Line
About 8 to 10% Fissure
About 30% Fissure
Rail Joint Pen for both lines of rails
These three lines for left-hand rails
About 16% Fissure
Small Fissure Line
Intermediate Size Fissure Line
Large Fissure Line
About 16% Fissure

Fig. 5. — A section of the record made by the detection in passing over a section of the special test track.

independent mechanically from the car frame, the only mechanical connection being that sufficient to hold the carriages properly in a vertical position and to move them along the rail. When in a raised position, the carriages are held rigidly against the frame of the car.

How defects are detected.

With this arrangement of brushes connecting the generator and the rails, the rail sections between the brushes on each side are energized and form parts of closed electrical circuits. When so energized, the path of the electrical flux through a section of perfect rail is constant. When a transverse fissure or other flaw is encountered, however, there is an immediate change or distortion of the direction of the current flux in the rail in passing around the obstruction, the severity of which indicates the relative size of the fissure or other flaw encountered.

Through specially designed apparatus mounted on each side of the car, all of these abrupt changes in the direction of current flow in the rail are detected. In addition, this apparatus interprets in terms of magnitude the changes in the current direction above referred to, and produces slight energizations which pass through electric circuits to amplifiers housed on a table in the center of the car. These amplifiers are of the ordinary heterodyne type, and step up the induced voltage approximately 25 000 times.

From the amplifiers, the amplified energizations pass to a group of 12 special relays, suitably arranged on a platform over the top of the table referred to, and connected in circuit with the recording pens and air valves on the paint-spraying equipment. The relay circuit for operating the recording pens carries six volts secured from the starting storage battery of the gas engine, while the relay circuit for the operation of the paint spray air valves carries from 80 to 110 volts, secured directly from the generator exciter.

Recording device indicates location and size of fissures.

The recording device for producing a graphical record of conditions found in the rail is substantially the same as used early in the year, this consisting of a recording table, on top of which travels a friction-driven strip of paper from a roll supply, which moves over the table at the rate of 1/16 inch per foot of track covered by the car. Directly in contact with the paper are seven pens which are actuated as the pen relays are affected by changes in the energy received from the amplifiers.

Fissures located in the two track rails are indicated on the paper by six of the pens, a group of three pens indicating the fissures in each rail. The seventh pen, which is located between the groups of fissure-indicating pens, records the location of joints. In recording the detection of a fissure, the relays are so adjusted that a short transverse line is drawn by one pen if the internal break is of intermediate size; and all three pens operate if the break is of large area. These three degrees of grading indicate roughly failures of 7, 15 and 25 % of the railhead area. Visual check on the proper functioning of the recording pens is afforded through suitable indicators connected across the output of each of the amplifiers.

Thus seven lines are produced on the graphical record—the three lines on the left indicating defects in the left-hand rails; the three lines on the right indicating defects in the right-hand rails, and the middle line indicating the position of joints. A numbering machine, which records consecutively the number of rail joints passed over on one side of the track, makes it possible to number all rails on the record which show the presence of transverse fissures.

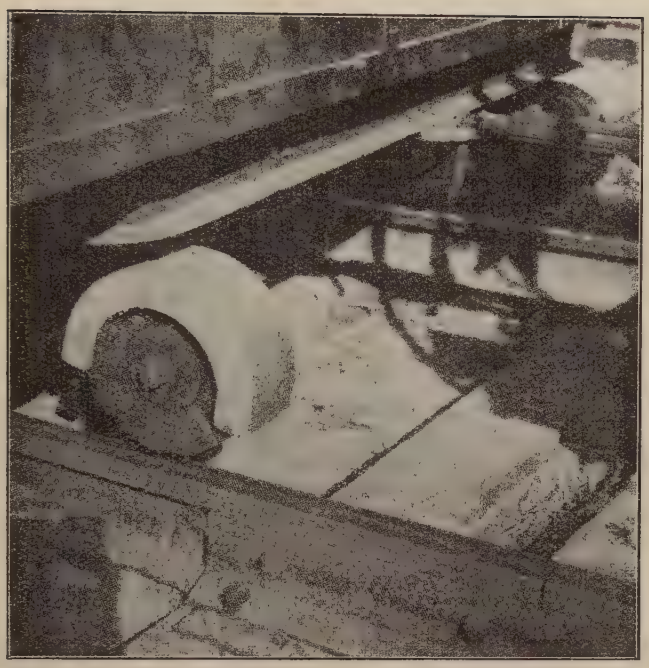


Fig. 6. — Rotary wire brushes clean the rail head in advance of the contact brushes.

Fig. 7. — The new detector car outfit of the Sperry rail service Company.

In addition to the graphical record produced by the pens, an actual indication of the location of fissures is produced directly on the track rails through the paint spray unit which forms a part of the detector car equipment. This unit, which was furnished by the De Vilbiss Company, includes a spray gun mounted on each side of the car and directed toward the web and base of the rails. Air for the operation of the guns is furnished by a small air compressor, which in mounted under the forward end of the car and driven through a belt connection with the shaft of the motor-generator set.

Operation of the paint spray gun on each side of the car is, in each case, through the opening and closing of a magnetic air valve located below the floor of the car and actuated by one of the relays. Ordinarily the gap between the rails at each joint would cause the paint spray equipment to operate, but this has been precluded through special devices which prevent the operation of the paint spray without affecting the operation of the pens.

Auxiliary equipment used on the detector car includes a speedometer mounted on the recording table, in order to keep a check on the speed at which the car is being operated; a switch and meter panel connected in the circuit of the generator current; a metal storage battery box, and a pair of rotary wire brushes for cleaning the surface of the head of the rail in advance of the contact brushes. These cleaning brushes, one of which is mounted directly over each rail at the head end of the car, are made of steel wire and are about 10 inches in diameter. Both brushes are belt-driven from the engine-generator shaft and operate at a speed of about 2 500 revolutions per minute.

First service run made on New York Central.

At the present time, the detector car is being operated over main line track under train order, by two men, in addition to the motor car operator in charge of the tow car, and a conductor and a flagman. No provision is made for setting the car off from the track, it being necessary for it to clear trains at passing tracks or other sidings.

In its first actual service run, which was completed only recently, the car was operated over the two main tracks of the New York Central between Beacon and Rensselaer, N. Y., a total distance of 166 miles. Within this territory approximately 53 000 rails were covered, which have been in the track an average of about 5 1/2 years. In all of this distance, defect indications were recorded on only 0.06 of 1 % of the rails, these varying from a few indications of relatively strong intensity to a greater number of indications of moderate or weak intensity.

Further details of the record established by the car on the New York Central are not available at this time, as a complete analysis has not yet been made of the results of the initial run, or of the record of a check run over a portion of the territory originally covered. On the initial run the car covered an average of from 18 to 38 miles per day, depending upon the conditions encountered, while on the check run, in wich record was made over portions of the track only, the car averaged about 40 miles per day.

Many assisted in developping detector car.

The experimental and development work which has resulted in the present transverse fissure detector equipment was begun about five years ago when E. A. Sperry of the Sperry Development Company, Brooklyn, conceived the idea of utilizing the air-gap resistance effect of disassociated particles or areas in the interior or rail heads to disclose their identity. Mr. Sperry oulined his plan to the Rail commitee of the American

Railway Engineering Association, and, after a careful investigation, an initial appropriation was made by the Association for a co-operative experimental study of the proposed plan in the laboratory of the Sperry Development Company. As a result laboratory equipment was designed and assembled which, under test, became so proficient that the size and location of each internal transverse fracture or fault in the rail head could be ascertained with a large degree of accuracy. Following these tests, an agreement was reached between the Sperry Company and the American Railway Association, in August, 1927, for the construction of a track car for the detection and marking of the internal failures of rails in the track. This car was completed early this year and was put under test on a special test track in the yard of the New York Central at Beacon, N. Y., in which were laid sections of rails in which transverse fissures had developed in service. While the results of the first actual service tests were highly encouraging, it was these results ant the results of subsequent tests made on the high speed main line tracks of the New York Central, which led to the final change in the method of detecting the location of fissures.

From the above, it is evident that credit for the succesful development of the present equipment for detecting and indicating the location of transverse fissures in rails in the track is due to a number of individuals and organizations; to E. A. Sperry and the Sperry Development Company; to the American Railway Engineering Association and the American Railway Association, and to the New York Central which has extended every assistance to further the successful completion of the car. Directly representing the Sperry Company during the development of the detector equipment has been H. C. Drake, assisted by J. A. Drain, Jr., while the American Railway Engineering Association has been represented by Earl Stimson, chief engineer, maintenance of way, of the Baltimore & Ohio, and chairman of the Committee on Rail; W. C. Barnes, engineer of tests for the Rail committee, and by C. B. Bronson, assistant inspecting engineer of the New York Central, and a sub-committee chairman of the Committee on Rail. The assistance given by the New York Central and all operations of the car on that road, have been under the direction of J. V. Neubert, chief engineer, maintenance of way. The operation of the car is under the general direction of the Rail committee of the American Railway Engineering Association, with direct supervision by W. C. Barnes, engineer of tests for the Committee. The operator of the car is Henry W. Keevil.

At the acceptance test of the detector car, which took place at Beacon on 2 October 1928, nine of the different roads having membership on the Rail committee of the A. R. E. A. had representatives present. While definite future plans for the operation of the A. R. A. equipment have not been formulated, under the present plan of operation, it is being assigned for a test period of six days to each of a number of roads in the East and South. Within this period each road has full jurisdiction over the actual operation of the car, using it on such lines as it may select.

Second car developped for commercial work.

In view of the demand being made for the service of the newly developed transverse fissure detector equipment and the desire of several of the roads to have their lines serviced by this equipment in the hands of experts, rather than to purchase one of these cars at this time and operate it themselves, the Sperry Development Company has rushed through a second car, which has been shipped to Chicago and is already operating on certain western lines.

Profiting by the experience gained in building the first car, the second car incorporates several additional features which are expected to facilitate the duties of the operator and produce a more valuable and effective record of the conditions found in the field. In the main, the electrical equipment and the principles involved are essentially the same as those embodied in the A. R. A. car.

Changes in equipment arrangement.

One of the principal changes in the newer car is found in the arrangement of the equipment within the car. In this arrangement, the newer car has a working space transversely across the center, and the space across the rear end is occupied by the amplifier and relay table, the meters, and the recording instrument table. So arranged, the operator can sit facing the rear of the car, watch his equipment, and at the same time have a clear view of both lines of rails behind him.

Another change incorporated in the newer equipment is in the recording instrument, where two additional pens have been provided. One of these pens is an additional joint indicating pen, so that there are two joint pens in the new instrument, one for each line of rails and the other is called a landmark pen. This latter pen ordinarily produces a continuous straight line, parallel with the other pen lines, but a jog can be produced in it when desired by closing a contact switch provided in the motor car which pulls the detector car. Thus, as the outfit moves over the track, the tow car operator, by closing the landmark pen contact switch beside him, can indicate directly on the record the precise locations of mile posts, bridges, signals, highway crossings, telegraph poles, etc. As he closes this switch to produce a landmark indication on the record, he advises the detector car operator of the specific object passed, over a telephone, so that the detector car operator can make a proper notation on the record opposite the indication made. In the telephone arrangement provided, transmission is one way only, and no provision is made for the detector car operator to talk with the tow car operator. In lieu of this, however, a buzzer circuit connects the two cars so that through a simple code, the detector car operator can transmit operating instructions to the tow car operator.

Brush lifter a feature.

Another feature included in the new commercial car, primarily as a precautionary measure against damage to the electrical contact brushes, is an air-operated brush lifter which raises or lowers the two brush carriages on the car separately. This is operated by the tow-car operator who raises the carriages each time the car is stopped. In order to preclude the possibility of a reverse movement of the car with the brushes in the lowered position, which in all probability would damage them at uneven rail joints, the brush-lifting device is arranged to work automatically, raising both brush carriages, with the slightest movement of the car in the reverse direction.

Special tow car is provided.

In order to adapt the commercial equipment to operation over heavy grades, and in inclement weather, the tow car provided for use with the detector car is a specially enclosed and equipped motor car. This car, which is a heavy-duty Kalamazoo inspection car with a 35 H. P. engine, is enclosed in a manner similar to the detector car, with glass panels on all four sides to give the operator a clear view in all directions.

As the operators of the detector car and tow car will, of necessity, be confined rather closely to the equipment both day and night while out on the road, the

tow car is suitably fitted to afford them conveniences and sleeping facilities. In the arrangement provided there is a small toilet room, a wash stand, fed from a large overhead water container, one permanently fixed bunk, and one movable bunk which is raised to the ceiling of the car during the day. In addition, the car is equipped with electric lights and is fitted with a comfortable wicker chair and a small table. The new detector car outfit just described, is being operated by the Sperry Rail Service Company, Chicago, a new company organized to give this service to the railways.

[621. 137.3]

The diagramming of locomotive workings,

By J. G. B. SAMS, A..M. Inst. M. E , M. Inst. L. E.

Fig. 1, p. 267.

(*The Engineer.*)

It must be very plain to all that the economical arrangement of the workings of locomotive engines are very complicated, and a matter for well-trained experts on each railway, observing that it is necessary to economy that every engine should run as many train-miles and as few light miles as possible in the minimum number of hours actually under steam per each lighting-up. It is also essential that the working of each engine be arranged so that the crew do not have excessive hours of duty, which means that the arrangements must allow of the crew being relieved by a fresh set of men somewhere near the expiry of their daily eight hours, or that the engine must arrive at a running shed somewhere about the expiry of that period — its base shed, if the working be a daily one, or a foreign shed if it be a working covering two days. A certain amount of latitude in hours is allowable, but no working should exceed ten hours for any one crew of enginemen, and workings under the eight-hour period are naturally uneconomical, as the men are paid for a minimum of eight hours per turn of duty, work or no work. This short working, however, cannot always be avoided.

The following remarks are intended to be helpful to those about to start their railway career whether in the traffic or locomotive departments; in addition, perhaps, they may be found informative to those in more responsible positions who may be looking for a new idea. The examples given have been taken from recent practice on English railways; but, of course, they may not be the actual workings at the moment, as alterations in the time-tables, and consequently to the engine workings, are frequent, and herein lies the best part of the work of the diagram arrangers, who must keep abreast of all alterations and additions, and at the same time work in all extra and special trains as economically as possible.

* * *

In the first place, let us review the chief rules governing the manning of engines. All duties must be arranged on an eight-hour day basis, and work, or a day's

pay in lieu, has to be found for all drivers and firemen on every weekday. Duties commencing at any moment on Sundays may not count for a day's work in place of an idle day during the week. Thus a turn of duty lasting from 11.55 p.m. on a Sunday to 7.55 a.m. on a Monday is a Sunday turn pure and simple, and a new turn of duty or a day's pay in lieu, must be found for this particular crew, starting at some later hour after the expiry of a proper rest period of eight hours on the same day.

Sundays and overtime are paid for at enhanced rates, and extra pay is given for long mileage irrespective of hours worked, the mileage being reckoned as 120 miles to one day's pay, all miles beyond that figure being paid for at the rate of 15 miles to an hour's pay. In order to save overtime, it is frequently necessary to have an engine prepared by a « shed crew, » who, in addition to preparation, sometimes work the engine from the shed on to the train, where they are relieved by the regular « road » men. A similar relief is sometimes necessary at the end of the turn, and examples will be cited of these arrangements. These shedmen are always juniors, often being « acting » rates—men passed for the higher rate but substantively in the lower—who take the higher rate when required, and the system of preparing engines for the road by juniors is usually considered undesirable, and consequently to be avoided, as it is known to informed circles that good enginemen prefer to prepare their own engines for the road, rather than be compelled to trust to others. Experience also is tending to show, both in this country and in America, that these juniors do not expend as much care on—to them—casual engines as the regular road crews are known to do, which in the end leads to an increase in failures on the road and heavier repairs bills. But if hours are to be kept down to a minimum, it cannot always be avoided.

As the duties of putting the engines away in the shed at the end of the day's work are comparatively unimportant they may freely be left to shed crews without prejudice to repairs or failures. Here it may be remarked that the time allowance for the preparation of engines is 45 minutes for those under 1500 square feet of heating surface, and 60 minutes for those over 1500 square feet.

The manning of engines on the foregoing principles can reabily be divided into six principal methods, namely :

1. Single crews daily.
2. Double crews daily.
3. Treble crews daily.
4. Single crews on two-day trips working from both ends.
5. The same, but working from one end only.
6. Changing footplates *en route*.

First method. —A single crew will take their engine out of the shed, perform the day's mileage according to diagram, return to their base shed and put their engine away themselves, if hours permit. If the turn be over the eight hours, it may be necessary for shedmen to prepare for the road or to dispose of the engine afterwards, or perhaps to perform both offices. Diagram A illustrates this method, which is obviously a small engine working, as only 45 minutes are allowed for preparation, which is diagrammed to be done by the road crew. Fifteen minutes are shown to be allowed in which to clear the shed and attach to the train, which is shown to leave for Ipswich at 10.10 a.m., 15 minutes being the usual minimum allowance, applicable to cases in which the running shed is right on the station. When this is not the case, more time, according to distance to be traversed and obstructions in the shape of traffic delays likely to be met, must be allowed, otherwise there will be a danger of delays to the starting of trains. As there are two routes between Cambridge and Ipswich, it is necessary to indicate the correct

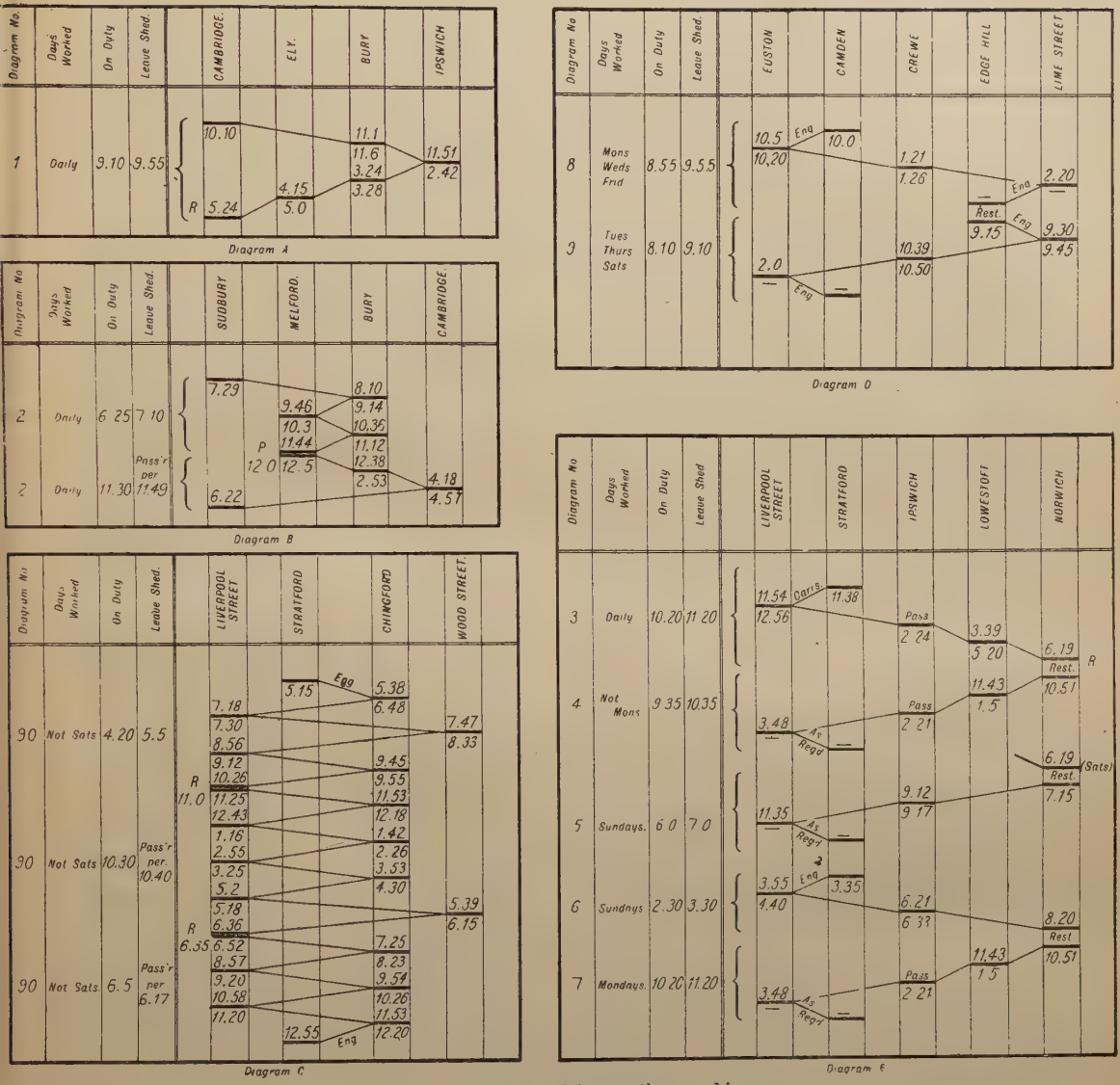


Fig. 1. — Diagrams of locomotive workings.

route on the diagram by showing the times of the train concerned at an intermediate station—generally the most important one—on the route traversed. In this case the train proceeds *viâ* Bury to Ipswich, where it arrives at 11.51 a.m.; the engine returning to Ely, *viâ* Bury, on the 2.42 p. m. train, working back from Ely to Cambridge on the 5.0 p.m. thence, the road crew being relieved on arrival at Cambridge by a shed crew, who put the engine away in the shed after the dispo-

sal of the train and any other shunting that may be required by the traffic department. The relief is necessary, as the road crew's hours expired at 5.10 p.m.

A word as to the conventions used on all the diagrams reproduced. All departure times are shown under the horizontal line, all arrival times being over it; these times referring to the station named at the head of the column in which they are to be found. Two parallel lines between the arrival and departure times at a station with an « R » opposite indicate that the first crew is relieved at that station by a second crew at the time shown. An « R » at the final arrival time indicates that the road crew is to be relieved on arrival by a shed crew.

« P » and a time indicate that crews have to travel as passengers between their base and the station at which the relief is diagrammed to take place, the actual relief taking place at the time shown. « Eng. » or « Carrs. » indicate a light engine or empty carriage train as the case may be; and the sloping lines indicate trains—including light engines—but the slope has no reference to the speed of the trains, being merely an indication that the train represented is one between the stations connected on the diagram running in the times given.

To return to diagram A. Summarised, this diagram consists of approximately 3 hours 35 minutes of actual train working with two intermediate terminals, the total train-mileage being 121 miles, the wages amounting to one day plus fifteen minutes' overtime for the road crew and a varying proportion of a shed crew's day's pay for putting the engine away, probably about a quarter-day on the average, the totals coming out fairly well for one lighting-up and a single road crew.

Second method. — Diagram B represents the daily working of a double-crewed country branch engine under 1 500 square feet of heating surface. The first crew work along the branch until relieved by the second crew who have travelled from their base to the relieving point by the train booked on the diagram. The first crew will return when relieved by the first available train, their hours of duty ceasing with its arrival at their base station—Sudbury on the diagram—the hours of duty of the relieving crew commencing at the booked time of departure of the train by which they are ordered to travel from their base. This diagram analysed consists of 5 hours 40 minutes of actual train-working with a mileage of 149 ½, inclusive of six intermediate terminals per one lighting-up. The mileage and working generally would appear to be fairly good for the expense of a double-crewed engine on this class of work—contry branches with an infrequent train service. One of the snags of this arrangement is that the engine must either be at, or else close to, the base station at or about the time that relief ought to take place; the latter case requiring a convenient train in each direction in order that the two crews may travel to and from the relief-point without waste of time. This may sometimes necessitate the running of the engine light back to the base for relief to take place.

Third method. — This is chiefly applicable to suburban services starting early in the morning and finishing late at night, accessibility for reliefs being a necessity. The first crew will take their engine from the shed and work through the diagram until relieved at the predetermined point by the second crew, who, as the service on which they are engaged does not permit them to finish out the working without excessive overtime, have to be relieved by a third crew who finish out the working and finally put the engine away in the shed. This three-crew method is also used for « continuous » engines, that is, engines

at work—such as shunting engines in busy yards—without a daily break in the shed, some of these engines hardly seeing the shed once a week. The relief crews for such engines are allowed « walking-time » to get from the shed to the engine, according to distance to be walked and time that may be taken in trains *en route* from the base to the shunting yard.

Returning to the diagram working, this requires that the engine be arranged to work a suitable train about the time necessary for relief through the base station, or as this is often impossible, through a nearby suitable station or to a convenient terminus. It is not always possible to avoid a litle overtime under this method owing to the trains not being conveniently timed for relief purposes, but what there is, is of a minor quantity.

Diagram C illustrates a three-crew suburban working, the engine proceeding light from its base (Stratford) to the commencing terminus (Chingford), from whence it begins the day's work. Ten minutes are allowed to get from the shed to the main line, and this is noted on the diagram. The convenient terminus for relief is Liverpool street Station, and the relief crews are booked on at Stratford about half an hour previous to their booked time for relief, this allowance varying according to the convenience of the train service between Stratford and Liverpool-street. On relief, the relieved men return home by the next train, their time expiring at Stratford Station, the final set of men working the engine home after finishing out. Owing to the rush ef engines coming in during the late evening at many large sheds, it frequently takes about ninety minutes or even more to dispose of the engine in the shed owing to congestion at the ashpits and the coal stage, which in this instance would only allow about two hours in the shed for the purpose of cleaning the engine and affecting any minor repair booked against the engine. In these short margins, the fire is usually left in after its cleaning over the ashpits.

This particular diagram gives an actual train-working time of 8 $\frac{1}{2}$ hours with a train-mileage of 175 miles for the expense of a day's wages and perhaps a fragment of overtime for the last shift for the three crews, which is good considering that there are nineteen intermediate termini.

Fourth method. — This method is used in connection with long-distance train working, and is illustraded by diagram D. Here an engine and crew work a down train (say) to a far point, and as the unexpired hours of duty do not admit of a return train without excessive overtime, the engine is put away in the foreign shed and the crew booked off until the following day, when they will work an up train to bring them home again. This working involves two engines and two sets of men, as one engine can obvioulsly only work in the same direction on every other day. As it is presumed that this train service is a daily one, a daily start must be made from each end by an engine belonging to that end. If a train in each direction on Sundays be imported into the working, it would be possible to run this method from one end only by sending one of the engines to the far end so as to make a start from there.

Looking at diagram D, which refers to the London engine and men of a pair engaged on this working, it is seen that the down trip runs on Mondays, Wednesdays and Fridays, returning with the up trips on the next day in each case. The complementary Liverpool engine works in the alternative direction to the above, so that the trains are engined daily and engines and men return to their bases every Tuesday, Thursday and Saturday, thus avoiding lodging away over the week-end or travelling

as passengers homeward in lieu. The diagram as shown can be converted into the complementary Liverpool working by putting the second half of the diagram as shown before the first half and altering the « rest » from Edge Hill to Camden.

The disadvantage of this arrangement is that the crews in each case have to take rest away from home, incurring six sets of lodging expenses thereby, but otherwise the arrangement is a very good one, as it gives 181 train miles in about four hours of actual train working for one day and four hours wages per lighting-up, and there are no intermediate termini, consequently the engine is under steam for the absolute minimum of hours. In selecting trains to be worked with this method, usually referred to as a « crossed » working, care must be taken to allow sufficient time for the crews' rest between the turns of duty, but at the same time it must not be too long, as lodging expenses increase in rate per hour after the expiry of twenty-eight hours away from the base station.

Fifth method: Diagram E. — In order to fill out hours of duty still available and to increase the miles run per lighting-up, a local train is added to the main line working on this diagram, which typifies a two-day working from one end, covering seven days per week and requiring two engines and sets of men. The inclusion of Sundays will be seen to be necessary in order to return the down Saturday engine and men and to provide for the up Monday working; without this the men would have to lodge out over the week-end, which would be expensive under the sliding scale mentioned above.

Coming to details of working, on Mondays to Fridays inclusive the engine and men of the 12.56 p. m. ex Liverpool-street work the 5.20 p. m. local train from Lowestoft to Norwich, book off duty and then take rest; coming on duty the next day to work the 10.51 a. m. local back to Lowestoft, thence the 1.5 p. m. express train to London. The engine and men for the 10.51 up local on Mondays have come direct from London—as shown—on Sunday with the 4.40 p. m. down train thence to Norwich, while the engine and men that have arrived on the Saturday with the 5.20 p. m. ex Lowestoft are utilised to work the 7.15 a. m. Sunday train, Norwich to London direct, proceeding thence « as required » by the empty carriage train working of the moment, these « as required » movements being usually left to the discretion of the local locomotive foreman working in co-operation with the traffic requirements. To show this Sunday working, the final fragment of the Saturday's diagram is repeated in conjunction with the entire Sunday diagram. Here it may be said that the word « pass » in a station column over a time indicates that the train is booked to pass through that station without stopping at the time mentioned.

The working shown in diagram E gives a train mileage of 145 miles for five hours actual train working with one intermediate terminus, which is hardly as good a case as the previous example.

Sixth method. — It is sometimes advisable to change footplates *en route* in order either to save overtime or to get men back to their base station. This cannot very well be done in the case of two passenger trains, but it is workable in the following cases, namely, between two goods trains, between a passenger and a goods train, or between two passenger engines meeting in a locomotive yard. As a passenger train is usually only allowed a minute or two at a station, a change of engine crews between it and a passing goods train necessitates the presence of the goods engine crew on the platform in readiness to step on

to the passenger engine immediately on arrival, thus leaving the goods engine without a crew for the space of a few minutes while the change is taking place. This method is often used between goods trains meeting at a station unprovided with a turntable in order to avoid the tender-first running that would ensue if the engines as well as the crews were to be changed over; but it is not considered a desirable system, as it tends to increase the pooling of engines, pooling being apt to foster neglect and so increase the quantity and cost of repairs, but it is a useful scheme at times for the avoidance of lodging-out expenses and of tender-first running.

Duty list. — The enginemen are usually advised of their prospective turns of duty by a « duty list », which is posted in one or more prominent positions about the running shed. Small sheds steaming up to three or four engines on regular schedules do not need such a list. as all the enginemen know all their turns by heart, and any casual alteration can be passed on to the men concerned by the man in charge, either in writing or by word of mouth. The duty list should be ruled in vertical columns, with spaces for the engine number, the names of the drivers and of the firemen, the number of the diagram to be worked, the time the engine is due to leave the shed, the time at which relief is to take place, and a wide « Remarks » column in which may be entered the train by which relief men are booked to travel, temporary alterations of diagram working, recent repairs and overhauls done to the engine which call for an extra amount of watchfulness on behalf of the enginemen, etc.

Relieving crews can be shown immediately under the crew that they are to relieve, but shed preparing and relief crews are best shown by themselves, each with a list of the engines that they are expected to prepare, or relieve and put away after. The road crews will know from their diagram what reliefs or preparation they are to receive. It is very necessary to advise enginemen of recent repairs, etc, to their engine through the duty list as well as by word of mouth, as many a newly adjusted big end, etc., has again given out through lack of the necessary additional attention, the excuse given by the culprits being that they had no knowledge of the matter whatever, and this is particularly applicable to engines and men working in a pool.

Neglecting additional wages cost, it is an indisputable fact that the recent reduction of enginemen's hours from ten to eight have complicated matters very considerably and have thrown additional burdens on to the railway companies. The relevant facts are that the running sheds and marshalling yards have grown up very largely on a ten-hour day basis; enginemen's hours ought to be longer than those of the train crews, as they have more duties to perform before and after the actual departure and arrival of their first and last trains, and there is much unavoidable waste of time at intermediate termini, reducing the net hours of work of both engine and crew, to say nothing of the waste in coal and wages. At a terminus it must be remembered also that an engine working in a train of carriages, generally speaking, cannot work the same train out again, but must wait for it to be worked away by a second engine, the first engine remaining in idleness until another train brought in by a third engine is ready to be worked away. This is not so with guards and other members of the train crew, who can always leave with the train that they have brought in.

The reduction has also increased engine changing *en route,* which carries with it an increase in intermediate terminals; a great deal of double and treble manning where formerly single and double manning was sufficient; also the increase of the pooling system and of preparation crews. All of these represent

additional expense and the engine changing additional complications for the diagramming staff as well as otherwise avoidable waste. Preparation crews represent waste, as in the busiest sheds they cannot be utilised all their time, observing that engines booked for preparation never follow each other at regular intervals, and it frequently happens that such a crew will only prepare two or three engines for a day's work representing a useful « day » of perhaps four hours. For the rest of their time they are « under shed foreman's orders », which usually means sitting in the mess-room waiting for something to turn up. An examination of engine workings will show that there is seldom more than five hours—generally far less—of net train working per crew in any turn excepting in those cases where the engines are prepared by shedmen or the roadmen are relieved on arrival, or where mileage runs are worked. A reasonable time for preparation, disposal, attaching, etc., is 2 1/2 hours per turn of duty, so that the proportion of train working time to attention, etc., time is at the best 2 to 1. A ten-hour day would increase this ratio, as attention time would remain constant, while it is reasonable to expect that train working time would be advanced two hours from five to seven hours, so that the proportion would improve to nearly 3 to 1. This must mean in the long run less engines in steam, a very material economy indeed, as well as the doubling of single-trip engines, *i.e.*, out-and-home-again runs with no lodging expenses instead of out one day, take rest, and return the next — applying the first method explained above instead of the fourth and fifth.

All these are very material points indeed that ought carefully to be considered both by the staff and the railway companies in connection with the return to prosperity without which no organisation can be expected to flourish and it has been truly said by a prominent railway general manager that there is more money to be saved in the running department of a railway than anywhere else.

A final suggestion is that when compiling time tables or arranging new trains greater co-operation should exist between the locomotive and the traffic branches with a view to elimination of waste. The writer well remembers that some years ago, on his railway, two long-distance trains were put on without any corresponding up working, the results being a heavy light mileage and the overloading with returning stock of some of the up trains. Much improvement might also take place by the amending of the time table to suit the economical working of engines and rolling stock. One is also struck by the curious fact that at junction stations formerly frontiers between different railways now amalgamated, original services on both sides of the frontier still terminate there instead of being joined up and running through, with the attendant advantages of better engine and rolling stock use, less intermediate locomotive terminals, and improved public service. Here, again, co-operation might well step in, improve services and save waste.

[621 .392 (.73)]

Welded construction for large shop building.

Figs. 1 to 8, pp. 274 to 281

(*Engineering News-Record.*)

Arc-welded steel construction for a shop building and yard craneway, with built-up members welded by an automatic machine of new design, is a not ble development in the new plant of the Mississippi Valley Structural Steel Company at Melrose Park, Ill., near Chicago. The welding includes built-up columns, large and small roof trusses, plate girders and a variety of details in stairs, hand rails and shop appliances. This company is making extensive use of welded instead of riveted construction for trusses, roof supports, lintels and other structural members.

This new plant, covering nearly twenty acres, has a punch shop 150 × 150 feet, a warehouse 340 × 135 feet and at right angles to the latter a riveting and assembling shop 85 × 125 feet. A 20-ton overhead crane of 80-feet span extends the length of the warehouse and similar cranes traverse the assembly shop and the shipping yard, this last having a runway 200 feet long. Welded construction was employed throughout for the warehouse, but for the punch shop riveted construction was used, since the curved-chord trusses had to be designed to carry a series of light traveling cranes and their make-up did not lend itself to convenient or economical welding. Figures 1 and 3 show the welded columns, girders and roof trusses of the warehouse.

Welded framing for warehouse. — This building, whose general design is shown in figure 2, has four rows of columns spaced 27 ft. 8 in. centre to centre longitudinally and forming a lofty 80-foot central bay with lower 26-foot side bays, the clear height from floor to truss being 34 feet in the main bay and 15 feet in the side bays. Longitudinal bracing includes vertical and horizontal diagonals between the trusses, the crane runway girders and diagonal cross-bracing between the columns in some of the panels. The light framing of the walls is attached to brackets or clips welded to the columns. Corrugated steel sheathing is used for the sides and roof, except that continuous steel sash is used above the low side roofs. Steel sash is used also for windows in the side and end walls.

Welded construction was used in building the columns, plate girders, roof trusses and trussed purlins. Field welding was employed in attaching the craneway girders to the columns and in uniting the two halves of each 80-foot truss on the ground before erection, these trusses being delivered in 40-foot welded lengths. Field connections for bracing were generally assembled by bolting and then riveted, as this was more convenient for erection. The trusses would have to be bolted temporarily, to hold them in place, and waiting while welded connections were made would have delayed erection.

Welded columns. — Built-up columns for the 80-foot bay, figure 4, have the lower part composed of a web plate 20 × 5/16 inches, with a 9-inch I-beam for the inner flange and an 8-inch chan-

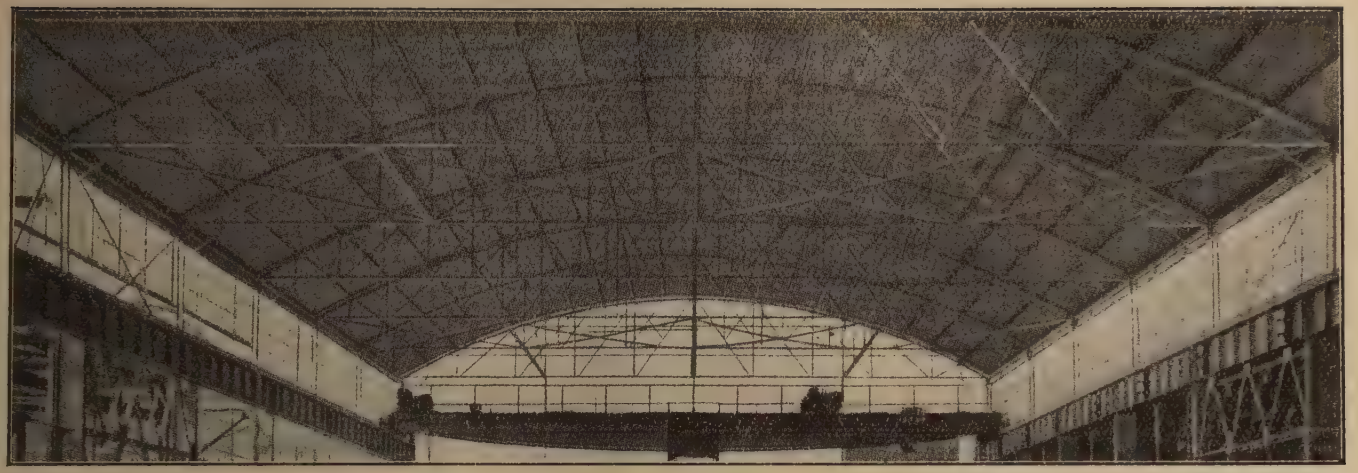


Fig. 1. — Welded roof trusses : 83-foot span.
Note absence of gussets, web members being welded to upstanding legs of chords.

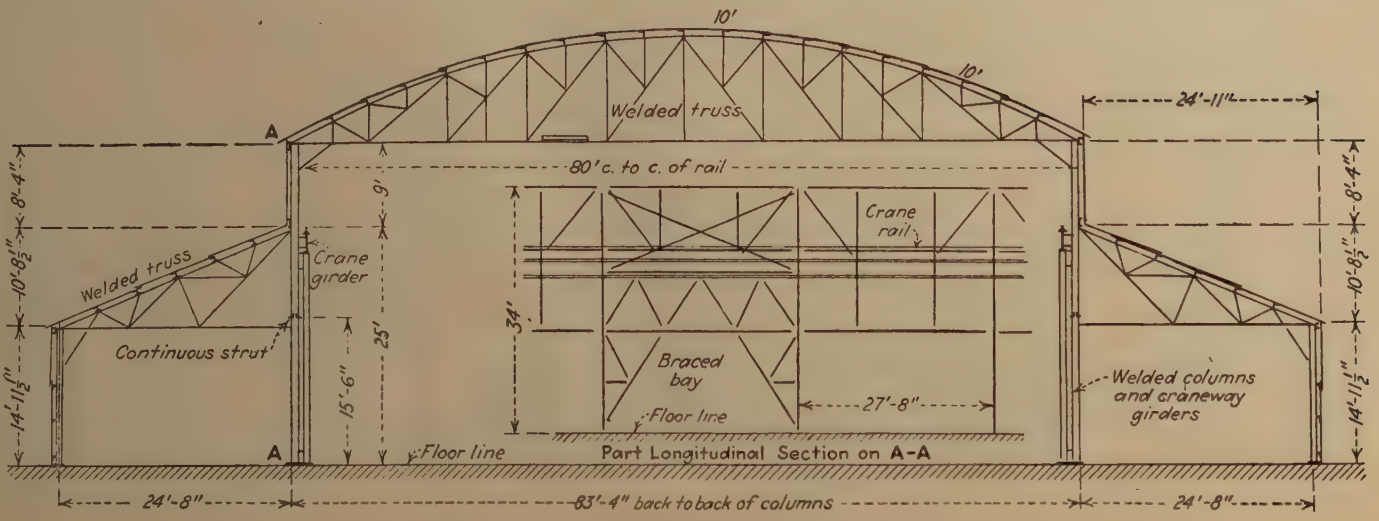


Fig. 2. — Typical cross section of welded building.
Insert, on smaller scale, shows typical longitudinal framing, including one braced panel.

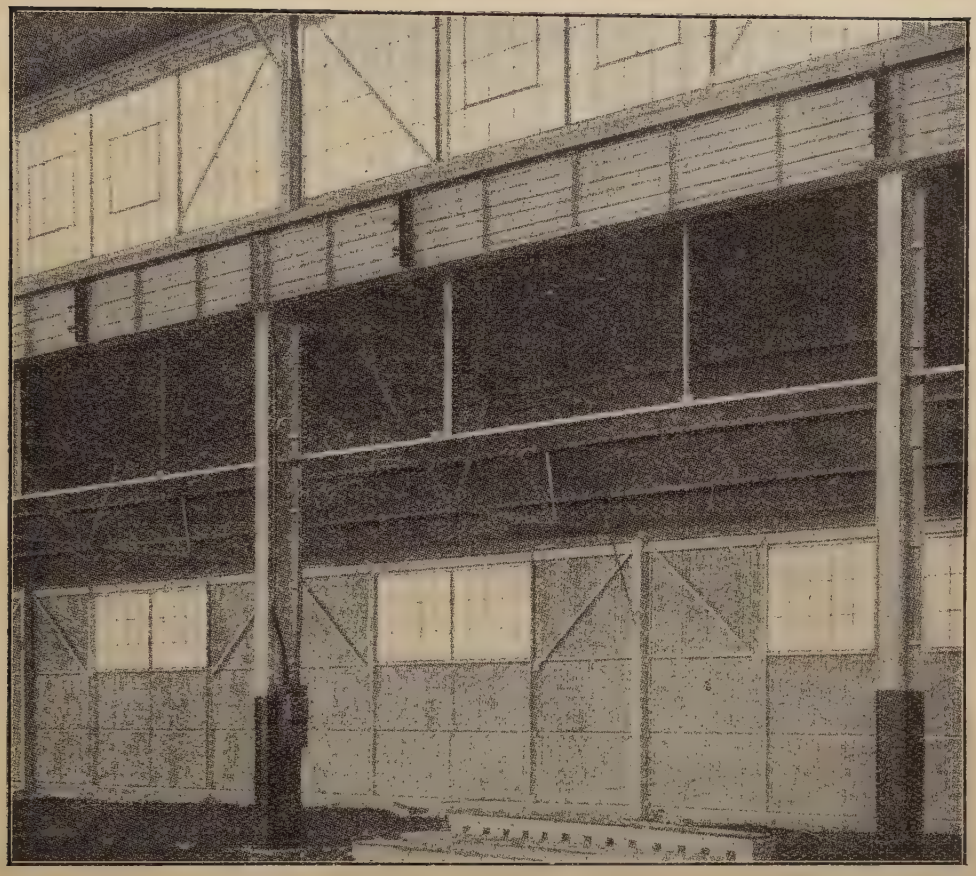


Fig. 3. — Welded framing of shop building.
Welded columns, built up of plates and shapes carry welded craneway girders and roof trusses.
Note diagonal bars welded to webs and flanges of columns.

nel for the outer flange. This latter extends the full height of the column, 34 feet. The I-beam extends to a height of 21 1/2 feet and is capped by a plate forming a seat for the crane girder. Above this the web plate is only 7 inches wide, and its inner flange is a plate 6 × 3/8 inches, forming a T-section. At its lower end this flange plate is slotted to engage the main web plate. The web plates are welded continuously to the flanges. To provide lateral strength, reinforcing the thin seam connecting the web to the flange, short diagonal bars 1 1/2 × 3/8 inches, about 18 inches apart and staggered, have their ends welded to the web plate and the flanges of the I-beam and channel and to the flange plate of the top or extension web.

The main web plate extends above the girder seat to form a gusset, against which the ends of the girder webs are butted. These three plates were field welded together as a solid connection. No expansion joint is provided in the 340-foot length of craneway. The co-

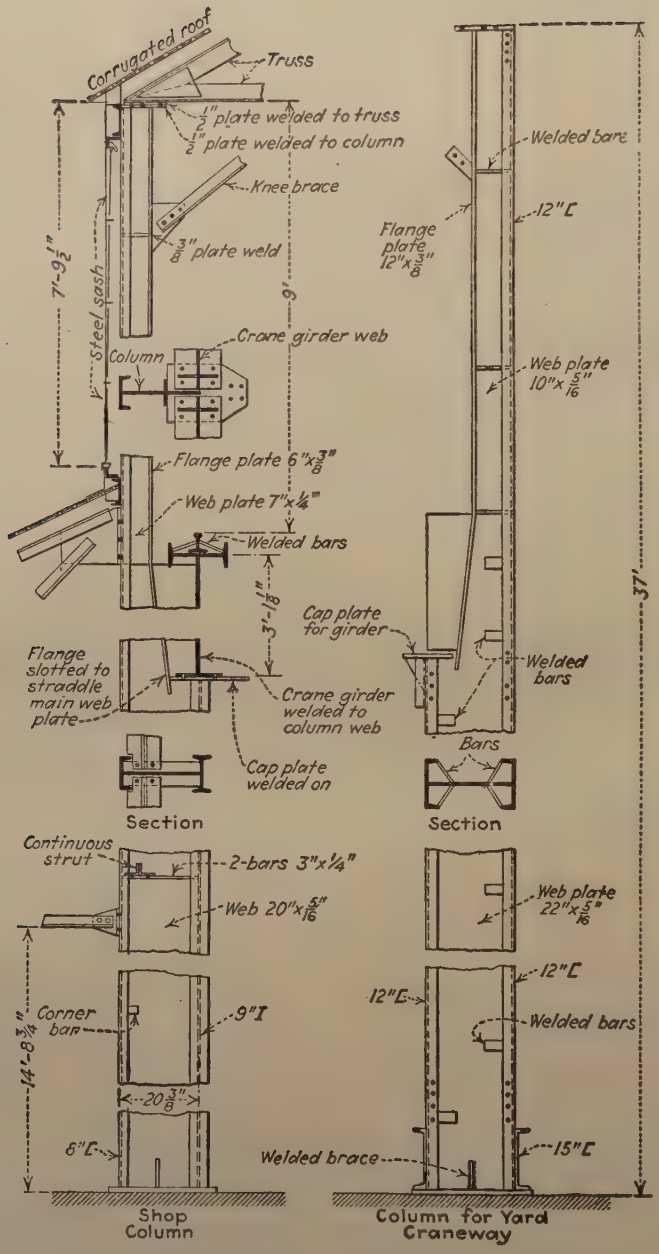


Fig. 4. — Built-up welded columns.

lumns of the walls and ends are not built up, but are rolled channels or I-beams.

Welded plate girders. — These craneway girders, figure 5, in lengths of 27 ft. 8 in., consist of a web plate 36 × 3/8 inches with a plate 12 × 9/16 inches for the bottom chord and a 15-inch I-beam, laid flat, for the top chord. The web stiffeners are plates 4 × 3/8 inches, spaced about 4 feet apart and welded to the web and chords. An 80-lb. rail for the crane is laid on the web of the I-beam and secured partly by bolted clips and partly by 3/4-inch rods, whose ends are welded to the web of rail and flanges of I-beams. Bent plates field riveted to the bottom chord form attachments for the longitudinal diagonal braces.

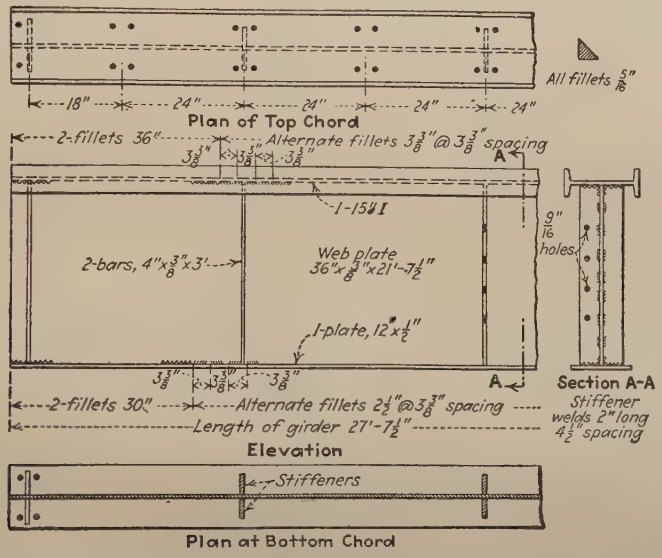


Fig. 5. — Welded girder for crane runway.

Welded roof trusses. — In the 80-foot trusses for the central bay, figures 1 and 6, the chords are pairs of angles welded together at intervals to make a T-section. At the ends the vertical legs of chords are cut to form a butt joint which is welded for its entire length, while under the bottom chord are welded bearing plates which are riveted to the cap plates of the columns.

Web members are composed of single or double angles having their ends welded to the legs of the chord angles. No gusset or connection plates are used, as in riveted trusses, and the absence of these improves the appearance of the finished roof. In erection, the welded trusses were found to be stiffer than riveted trusses of the same general size and type. The truss weighs about 2 1/2 tons, ready for erection. Its depth is 11 feet at the middle, and its top chord has a radius of about 83 feet, or the exact length of the span.

The 26-foot triangular trusses of the side bays are also welded, built up of light angles. They are field riveted to the wall columns and to the sides of the tall columns of the central bay.

Yard craneway. — For loading material in the shipping yard there is a 20-ton

traveling crane of 80-foot span on a runway of somewhat similar construction to the warehouse framing. The columns, figure 4, extend above the runway girders and have caps and connections welded in, so that a roof can be placed later and shop painting done here under cover. In these columns, however, both flanges are 12-inch channels, instead of having an I-beam for the inner flange, while the web plate is 22x5/16 inches.

As there is no cross-connection at the top, these columns must have a heavier anchorage than the shop columns. For this purpose short pieces of channels are welded across both faces of the column, at the bottom, and the anchor bolts extend up through the flanges of these channels. For lateral support also an inclined brace is riveted to the outside of the column at the level of the craneway and extends to an anchor block. When a roof is placed, connecting the columns into a single structure, these wind braces may be removed.

Welding machine. — The economy and advantages of an automatic machine for extensive work in welding structural steel members had been realized for some time by G. A. Caldwell, general superintendent of the company. With welded construction adopted for the new plant, an opportunity was afforded for experimenting with this development, since both design and fabrication of the structural material were under his control. A machine designed by him was built therefore at the company's plant at Decatur, Ill., where the material for the Melrose Park plant was fabricated. Fundamental claims for a patent for this machine have been granted, and Mr. Caldwell has applied for patents covering the principal features.

In this machine, shown by figures 7 and 8, a long table supports power-driven rolls carrying the material forward at a speed that can be varied by the operator from 2 inches to 40 feet per minute, to suit the work. The rolls are reversible, so that material can be fed from either end of the table.

Near the middle of the table and above it are two sets of guide rolls, which hold the members or parts in proper position while the welds are being made. Above the work is a hold-down roller moving in guides and applying pressure to insure close contact between the pieces that are being welded together. All these rolls are adjustable, so that the machine can handle a large variety of shapes and sizes.

On each side of the table and near the middle of its length are two automatic welding heads, which are adjustable vertically, laterally and longitudinally to accomodate the various sizes and different methods of welding. Each head is wired to its own control panel and is also wired in step with the driving mechanism of the feed table.

This latter arrangement simplifies the control, as the closing of one electric switch is sufficient to change the operation from continuous welding to automatic stitch welding, the stitch or intermittent welds being of uniform length and spacing. Any desired length of stitch may be welded and the spacing may range from 3 3/8 to 27 inches. Stitch welding includes the following series of steps, all automatic : 1. Cutting off the arc; 2. Speeding up the travel of the material to the next weld; 3. Slowing down this travel to a speed at which welding can be done; 4. Striking the arc; 5. Making the weld or stitch of prescribed length.

Two men operate the machine, one acting as a helper in placing the material and watching the second arc. In welding both columns and girders, the flanges were held to a tight bearing against the webs, and it was found that this was an essential factor in making good welds.

Welding built-up columns. — This work may be described as an illustration of the methods employed in ma-

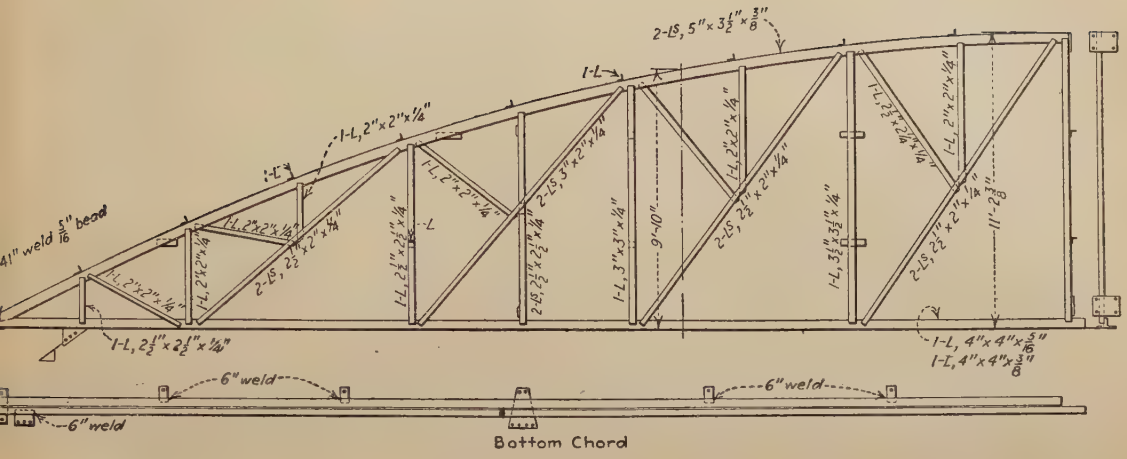

2-LS, 5" x 3½" x ⅜"
1-L
1-L, 2" x 2" x ¼"
1-L, 2" x 2" x ¼"
2-LS, 3" x 2" x ¼"
1-L, 3" x 3" x ¼"
9'-10"
2-LS, 2" x 2" x ¼"
1-L, 3½" x 3½" x ¼"
1-L, 2½" x 2" x ¼"
11'-2⅜"
2-LS, 2½" x 2" x ¼"
1-L, 4" x 4" x 5/16"
1-L, 4" x 4" x ⅜"
6" weld
6" weld
6" weld
Bottom Chord

Fig. 6. — Detail of welded roof truss.

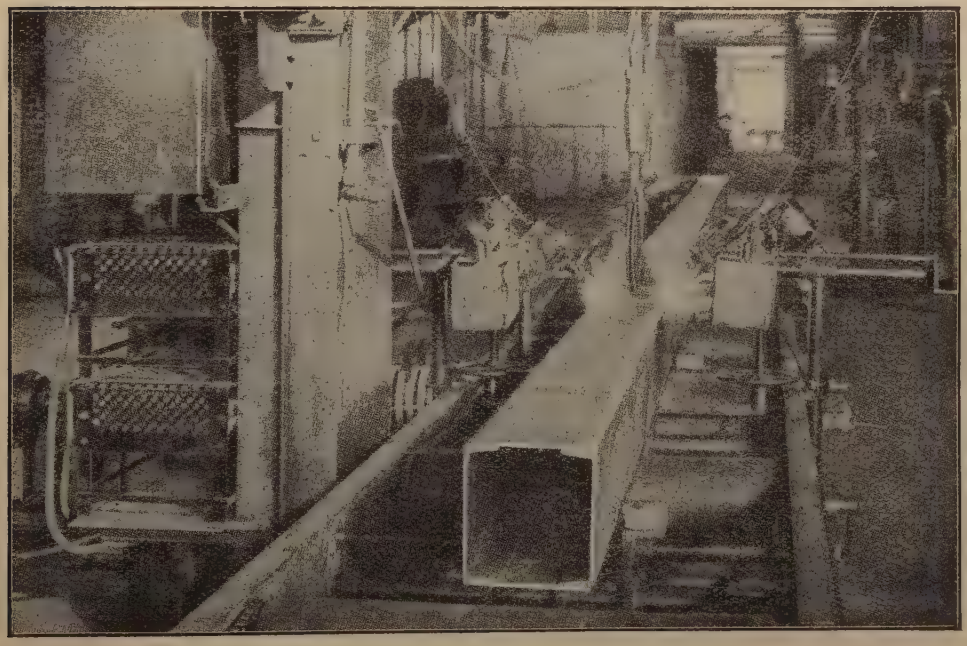


Fig. 7. — Automatic welding machine for structural steel.

Box column on driven feed rollers, with guide rollers at side and top roller holding down cover plate. Welding head on each side of column. Note long end welds followed by intermittent stitch weld.

chine welding. In preparing the material, the main and extension web plates and the flange plates for the extension webs were sheared to length, and the flange plates were slotted, as described. The I-beams and channels for the columns were cut and milled to length and punched on a spacing punch for field connections. These several parts were then stacked conveniently near the machine. All field connection holes, except those for details, were made in the webs of the channels, thus simplifying the punching and reducing the amount of material to be handled at the punches.

Material for columns having been assembled, the welding heads were adjusted to the proper position and angle. As the major part of these seams consisted of stitch welds 9 inches apart, staggered on opposite sides of the web, the electrodes were spaced 4 1/2 inches centre to centre longitudinally. The speed of travel was adjusted to 7 3/4 inches per minute while welding and 44 feet per minute in shifting to the next weld. The first operation was welding the flange plates to the small or extension webs, forming T-sections. These parts were laid aside and the I-beam inner flanges were welded to the main web plates and stacked ready for use.

For welding the channel forming the outer flange on the entire length of both main and extension webs and thus completing the column, the operations were as described below from a statement prepared by Mr. Caldwell. This description will be understood by referring to figures 7 and 8, although these represent the welding of a box column and a plate girder, respectively.

The channel for the column was placed on the table rolls, with its flanges upward and its bottom end toward the welding head. The main web, with the shorter I-beam flange already attached, was then placed with its edge resting on the center line of the channel, and the assembled parts were advanced through the guide rolls to the first electrode. There the channel rested on the middle roll of the table, a little higher than the others, and the hold-down roller was lowered to put the pieces under pressure.

With the work in this position, the operator closed two switches controlling the travel and the first electrode respectively. This electrode then struck its arc and continued to weld as the material advanced. When the column reached the second electrode, the operator closed its switch and it also began welding, so that two seams were being welded, on opposite sides of the web plate and 4 1/2 inches apart. This continued until the length for continuous welding was completed. Then the operator closed a fourth switch, and stitch welding proceeded until a point was reached near the end of the web, where a continuous weld was desired on account of the load from the crane girder. For this, the operator opened the fourth switch, and continuous welding proceeded until the end of the plate reached the first electrode.

Welding was then stopped while one of the T-sections already welded to form the extension top of the column was placed in position, the continuous welding being then continued, attaching the web of this extension to the web of the channel. This completed the machine work, and the column was removed to have the details welded on by hand.

These details included the base plate, cap plate on top, cap plate on inner flange to carry the craneway girder, a bar on the inner flange as a connection to a kneebrace on the roof truss, and the crossbars from web to edges of the channels and I-beams. The craneway cap plate was let into the web of the column by notching the latter with a torch, the notch being afterward closed by welding the web plate to the cap. The forked end of the inner flange plate of the extension top of the column was bent over and welded to this cap plate and stitch welded to the main web plate.

The abutting ends of the main and extension web plates were also welded together to form a continuous web.

Welding crane girders. — Each plate girder had the bottom flange plate cut 1/4 in. short at the ends, to clear the fillet made on the cap plate in welding this plate into the notch of the colmun web, as already described. As shown by figure 5, four holes were punched in each end of this flange plate for connections to the cap plate, and four holes in the top flange for the rail clamps. Holes were punched also in the stiffener plates for the electric wiring of the crane.

Welding the girders was less complicated than welding the columns, since only two double seams were required, attaching the chords to the web. The speed for welding was reduced to 5 3/4 inches per minute. while the speed of travel between welds remained at 40 feet per minute. For the lower chord, there was a continuous double seam 30 inches long at each end and 6 3/4 inches apart on both sides of the web, but staggered in position. For the top chord, the continuous end welds were 36 inches long and the stitch welds 3 3/8 inches long, these latter being practically equivalent to continuous welds. The end and intermediate stif-

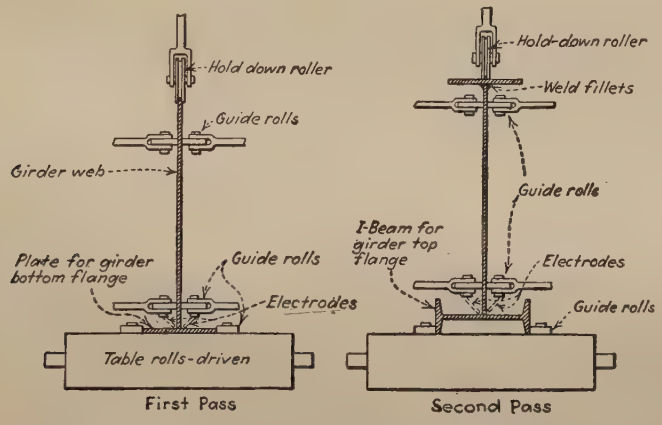


Fig. 8. — Welding a plate girder on automatic machine.

At left first pass through machine to weld web plate to plate for bottom flange, At right, second pass, to weld web to I-beam for top flange of girder.

feners, 5 × 1/2 inches and 4 × 3/8 inches respectively, milled to a driving fit, were stitch welded by hand, completing the girder.

Tests of girders. — Coupons tacked at the ends of the seams of one girder were welded on by the machine as the work proceeded. When knocked off and pulled in a testing machine, they showed values of 7 600 to 9 400 lb. per linear inch of weld. Under a test load of 58 tons distributed over a length of 6 feet at the middle, the girder showed no signs of failure in the welds. The deflection was 5/16 inch and the stress in the bottom chord about 26 000 lb. per square inch.

No warping or distortion was noticeable, except that where two continuous welds were made at the ends of the bottom chords the flange plates were slightly troughed. This effect appeared to a less degree at the ends of columns, where two continuous seams were made.

Designers. — The layout of the new plant and the structural designs of the buildings were done by the company's staff; the material was fabricated at the company's shops at Decatur, Ill., and was erected by its own field forces. All this work was under the direction of W. M. Wood, president of the Mississippi Valley Structural Steel Company; G. A. Caldwell, vice-president and general superintendent (who also invented the welding machine), and R. D. Wood, general manager.

As to the results of this work, Mr. Caldwell has made the following statement :

« From the rate of travel and the welding speed the time consumed in making a welded seam can be figured, and this time will correspond closely to the observed time or number of these seams. Costs also can be figured, and it will be apparent that there is some saving over riveted work. This also checks with our cost sheets on this job. Alto gether, it was a very satisfactory adventure, and we have been widely complimented on the appearance of the work. »

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Projected extensions of the main line stations in Paris,

By Mr. DUCHESNOY.

(*Les Chemins de fer et les Tramways.*)

During recent years the main line stations in Paris have been found inadequate. The suburban service especially is very heavy, not only through the train movements required, but above all because of the additional shunting movements resulting from the use of steam traction and from certain local conditions : necessity for bringing in an engine for each rake of carriages arriving to which it has to be coupled to work it away, and for despatching the engine that worked the rake into the station; impossibility of holding in the stations during the slack hours the rakes of stock required by the traffic at busy times, and the necessity of sending them to more or less distant holding sidings from which they have to be brought back into the station when required. In addition, the Companies working trains in connection with transatlantic steamship sailings and to seaside resorts (Nord, Paris-Orleans, and State) have to run trains to suit the departure of the boats and, more especially, their arrival, frequently at unexpected times, as well as trains to seaside resorts much frequented at particular periods and at certain holidays. In this way it is frequently necessary to run in the intervals of the already very heavy normal service a large number of supplementary trains, the timings of some of which may possibly be altered considerably. In order to meet such sudden changes in the traffic, the Paris stations require a number of reserve platforms in order to give all the needed elasticity of working.

As regards the suppression of additional shunting movements of engines and stock, an excellent solution lies in the electrification of the suburban lines with rakes of stock which can be split up as desired and be run in either direction, the stock being fitted with automatic couplings.

We propose in this article to consider briefly the present position in the various stations in Paris and the measures taken, or under consideration, to enable them to carry out their service in a proper manner. The lack of capacity of these stations lies not only in an insufficient number of platform lines, and lines leading thereto, but also in too slow methods of dealing with luggage on the platforms and in lack of circulating area.

The problem of improving the stations in Paris has to be considered from two aspects : extension of the railway equipment properly speaking, re-arrangement of the courtyards and roads leading from the station towards the main traffic arteries of Paris.

WORKING IN THE PARIS STATIONS.

a) Gare de l'Est

The Gare de l'Est (Eastern Railway Station) deals with main line traffic in

three directions : Mézières-Charleville, Luxembourg-Metz, Strasbourg and Mulhouse, and a suburban service (Château-Thierry, Longueville, Gargan). Until recently it contained 16 platforms 220 m. (722 feet) long on an average. The number of passengers increased from 16 800 000 in 1900 to 40 000 000 in 1927, or an increase of 137 %. At the busiest times, the number of trains reached 19 (period from 7 to 8 a. m. for arrivals and 6.20 to 7.20 p. m. for departures). The first improvement has just been completed by providing two additional platforms alongside the rue du Faubourg-Saint-Martin raising the number of platforms to 15. If we take as the index of comparison between the different stations the quotient of the number of passengers V during the busiest hours by the number of platforms available Q we get the value

$$I = \frac{V}{Q} = \frac{13\ 300}{18} = 739.$$

In order to cope with the growth of passenger traffic, the Eastern Railway put in hand three years ago a considerable extension of the station, involving the removal of the parcels offices, customs, and offices, and the laying of 10 new lines on the site thus obtained. This extension involved a deviation of the rue du Faubourg-Saint-Martin between the rue de Château-Landon and the rue des Récollets, and the re-arrangement of the actual passenger station building which will be rebuilt bordering the present courtyard and across the whole front corresponding to the 28 roads. These lines will be carried right up to the new building : the present lines will thereby be lengthened about 80 m. (26 feet) so as to save passengers with luggage their long walk of 140 m. (459 feet) between the barriers and the platforms.

The station will in this way have at its disposal 28 platforms averaging 300 m. (984 feet) in length. It will be served by 8 running roads, two of which are reserved for the use of locomotives and stock trains.

b) **Gare du Nord**.

The Gare du Nord (Northern Railway Station) deals with main line trains (five directions : Le Tréport, Boulogne, Lille, Maubeuge and Hirson) and inner and outer suburban trains (Saint Denis shuttle service, Creil line, Crépy-en-Valois, Persan-Beaumont, Pontoise). During race days at Chantilly the service increases considerably, necessitating the movement in a very short time of a large number of passengers.

The station now has 19 lines, averaging 240 m. (787 feet) in length for the main line and suburban services, five short lines (110 m. = 361 feet in length) for the St. Denis trains, and four lines for parcels work. During rush hours, the number of trains reaches 31 (arrivals 7 to 8 a. m.) and 35 (departures 6.20 to 7.20 p. m.) including 5 and 6 St. Denis trains. The number of passengers carried per hour at the peak period is about 21 500, of which 1 200 by the St. Denis trains. The index has the value :

$$I = \frac{21\ 500}{24} = 896.$$

The Northern Railway Company is considering the extension of the station on the following lines : the arrival yard and the parcels service will be removed from their present sites which will make it possible to re-arrange the St. Denis line and the parcels lines, as well as to lengthen them. The station would in this way have 28 lines of an average length of 250 m. (820 feet). The parcels service and the arrival yard would be provided either underground or overhead above the ends of the lines with connection with the rue du Faubourg-Saint-Denis at its present level, and at the other with the rue Ambroise-Paré suitably raised and graded.

The station would continue to be work-

ed by 10 incoming roads, 2 reserved to the St. Denis and parcels services and 2 to the locomotives and stock trains.

c) **The Paris-Orleans station.**

The Paris-Orleans Company in its Paris stations deals with a large number of main line services (three directions : Saint-Nazaire and Quimper; Bordeaux and Spain; Toulouse, Agen, Eygurande and Mont Dore) and a suburban service (Juvisy, Etampes and Dourdan, Choisy-le-Roi and Massy-Palaiseau) which is growing rapidly since the Company electrified the lines out to Vierzon.

The Gare d'Orsay has 10 passenger platform lines, 4 for departures, 2 for main line arrivals and 4 for suburban trains. It is not capable of extension. The number of passengers arriving and leaving annually averages 9 millions.

The Gare Saint-Michel is a through station. It has only two lines. The traffic amounts to 6 400 000 passengers annually.

The Gare d'Austerlitz has 8 through lines. The number of passengers using it is 7 200 000 a year.

The number of trains per day in normal working is :

KIND.	Departures.	Arrivals.
Main lines	26	26
Suburban	53	55
Empty stock trains .	26	24
	105	105

or a total of 210. This figure at busy times can be as high as 275.

To these numbers must be added 30 express goods trains.

During the rush hours, the movement of trains is 17 arrivals (7 to 8 a. m.) and 14 departures (7 to 8 p. m.). At this period the movement at the Gare d'Orsay may be as much as 7 000 passengers. The index therefore has the value :

$$1 = \frac{7\ 000}{10} = 700.$$

In order to facilitate the working of the Gare d'Orsay, which is very difficult, and owing to the electrification of the lines as far as Orleans, the Company is considering the removal of the fast goods or parcels service from the Gare d'Austerlitz to Ivry, and on the site thus liberated to build at the Gare d'Austerlitz a terminus for the electric trains with 6 lines of 240 m. (787 feet) useful length.

d) **Gare de Lyon.**

The station has during two periods of the day, each of 5 hours, to receive and dispatch at very close intervals a large number of trains, namely :

Arrivals (between 5 and 10 a. m.) :

Suburban	33
Main line	43
Total . . .	76

Departures (between 5 and 10 p. m.) :

Suburban	34
Main line	27
Total . . .	61

The total number of passengers arriving and leaving yearly amounts to 22.8 millions — 15.2 millions suburban and 7.6 main line.

On certain busy days the number of incoming and outgoing trains during the day may be as many as 200 during the 24 hours corresponding to a figure of 70 000 passengers instead of 185 trains and 60 000 passengers in normal periods.

The service covers four main line directions (Besançon, Pontarlier, Switzerland; Grenoble, Modane, Italy; Lyon, Marseille, Italy; Clermont, Nîmes) and a suburban service (Montereau via Brunoy and via Héricy lines, and Montargis via Malesherbes and via Moret lines).

The station to cover this work has to use all its 12 available lines each averaging 280 m. (919 feet) in length. The mo-

vement during the busiest hour reaches : 14 trains (arrival period 7 to 8 a. m.) and 15 trains (7 to 8 p. m.) : with 10 500 passengers.

The index would thus have the value

$$I = \frac{10\,500}{12} = 873.$$

The Paris, Lyons and Mediterranean Railway Company has started to carry out an extension of the Gare de Lyon on the following lines : the workshops and other Running Department buildings near the rue de Châlon have been transferred to Villeneuve-Saint-Georges : on the site thus liberated the Parcels Department has been placed which made it possible to build on its former site a departure station having 9 tracks. The complete station will in this way have 21 tracks.

In the future, the Paris, Lyons and Mediterranean Company consider this number can be increased to 28 by extending the station towards the rue de Châlon: 7 new tracks will be provided and the tracks of the first extension will be lengthened so as to give the 28 tracks of the future station a useful length of 340 m. (1 115 feet).

Access to the station is given by four running roads and two other roads reserved for locomotive and stock train purposes.

e) **State Railways**

The lines of the State Railways terminating in Paris include both main lines and also suburban lines.

The main lines are divided into six principal directions :

1. Dieppe line via Pontoise;
2. Le Havre and Dieppe line via Rouen;
3. Cherbourg and Trouville line;
4. Granville line;
5. Brest and Angers, Saint-Malo and Redon line;
6. South west lines (Bordeaux, La Rochelle and les Sables d'Olonne).

The suburban lines includes both the outer and inner suburbs.

The outer suburban service includes :

1. The Mantes line via Argenteuil;
2. The Mantes via Poissy and Pontoise via Achères lines;
3. The Dreux, Chartres and Mantes via Plaisir-Grignon lines.

The inner suburban service includes :

1. The Versailles R. D. (right bank of the Seine), Les Moulineaux and l'Etang-la-Ville lines;
2. The Saint-Germain line;
3. The Argenteuil line;
4. Paris-Montparnasse to Versailles R. G. (left bank of the Seine) line;
5. Paris-Invalides to Versailles R. G. line.

These various lines are distributed between the three Paris stations as follows:

Saint-Lazare station deals with the main line trains for Dieppe, Le Havre, Cherbourg and branches, the outer suburban (Mantes and Pontoise) and the inner suburban R. G. (left bank of the Seine) (Versailles, l'Etang-la-Ville, Moulineaux, Saint-Germain, Argenteuil).

The Invalides station deals with the Granville and Versailles R. G. lines, and some main line trains for the Rennes lines, the outer suburban trains from Dreux and Mantes via Plaisir-Grignon and some trains from Rambouillet.

The Montparnasse station handles the main line trains for Brest and the South West, the suburban trains (Clamart and Versailles R. G.) and the outer suburban trains for Chartres. This station will also be the terminus for the new line, Paris to Chartres via Gallardon, which will have a suburban working as between Paris and Orsay.

The total number of passengers departing or arriving by each of the three main stations of the System has grown during the last twenty years in the following proportions :

	Stations		
	Saint-Lazare.	Montparnasse.	Invalides.
Year 1900 . . . . . Millions.	51	7.6	Not fully open to traffic.
— 1906 . . . . . —	...	...	2.6
— 1913 . . . . . —	58 2	9.7	4 9
— 1921 . . . . . —	68.5	13	9
— 1926 . . . . . —	72.6	14	9.6
Increase . . . . . —	21.6	6.4	7
— . . . . . Per cent.	42 %	84 %	270 %
Average annual increase	834 000	257 000	427 000

SAINT LAZARE STATION.

Saint Lazare at the present time has 27 platforms served by 27 lines, numbered 1 to 27, and 4 additional lines (duplicate lines laid between certain platform lines). The 27 lines deal with the main line inner and outer suburban trains and the other 4 with supplementary services (such as Post Office).

The platforms 1 to 16 are normally allotted to the suburban service, and platforms 17 to 27 to the main line and outer suburban services. The suburban service covers the Versailles, Saint-Germain and Argenteuil lines. The main line and outer suburban services cover the two Mantes lines, the Pontoise (outer suburban) line, and the Dieppe, le Havre and Cherbourg lines.

The movement of trains during the peak hour (departures between 6.20 and 7.20 p. m.) amounts to 35 which gives for certain groups of lines 11 trains per hour, a figure only possible of attainment with electric traction, 10 trains an hour with steam traction being considered very difficult to work. To these movements must be added the auxiliary movements which at the present time reach the following figures :

Empty Stock	132
Light engines.	180
Fast goods	58

without taking into account the inward movements of locomotives bringing in number of outer suburban trains.

The electrification of the suburban lines which should be completed next July by that of the Versailles R. D. line will make it possible to reduce the supplementary movements, but will increase the number of trains leaving and arriving. Ultimately, the movement during the busiest hours will reach on the departure lines (6.20 to 7.20 p. m.) 44 electric trains, 8 main line and outer suburban steam trains, and 5 supplementary steam train workings, and on the arrival lines (7.45 to 8.45 a. m.) 44 electric trains, 13 main line and outer suburban steam trains, and 7 supplementary steam train workings.

In addition, account must be taken of the continuous growth of the outer suburban area owing to the development of many building estates between Paris and Mantes which, in the near future, will lead to an increase of about 50 % in the number of outer suburban trains.

If the year 1900 be excluded as being exceptional owing to the International Exhibition, the growth in the number of passengers during a period of twenty years shews the following figures :

	Increase.	
	Number.	Per cent.
Suburban.	15 500 000	39
Main lines	6 700 000	108
Total . . .	22 200 000	48

The increase averages 2.4 % per annum. In ten years' time the passenger traffic at Saint Lazare may be expected to amount to 80 to 90 millions annually.

Not only does the total number of passengers increase, but also during recent years the periods of intense traffic have shortened as a result of the 8-hour day. Formerly, workmen living in the suburban area arrived in Paris very early and left very late when the ordinary passenger traffic had not started or was almost over At the present time almost everybody arrives or leaves during a very short period.

In 1910, the number of suburban passengers handled during the busiest hour (6.30 p. m. to 7.30 p. m.) was 13 000. This figure had grown in 1920 to 18 000 and to-day is 35 000.

The index of the Saint-Lazare station therefore has grown to $\frac{35\,000}{27} = 1\,300$.

Il must also be kept in mind that as the electrification is completed the western suburbs will expand more and more. The public is buying much land in the inner and outer suburban areas on which new houses are being built.

The State system will therefore be led to a further large extension of Saint Lazare in a few years' time. It can only do it by carrying out the projected underground station which could of course be done by providing first of all a station for the reception of trains from the Versailles and Saint-Germain lines, and subsequently another for the Argenteuil line.

The projected scheme provides a group of two lines for each of the directions electrified (Versailles, Saint-Germain, Argenteuil) the underground station having 4 platforms for each direction. This station would be in direct rail communication with stations on the Metropolitan and Nord-Sud Railways.

In addition, it appears to be necessary to open up the approaches to the Saint-Lazare station : at certain hours the circulation in the Saint-Lazare, le Havre, Rome and la Pépinière streets, is almost completely blocked. It would be possible, in conjunction with the City of Paris authorities, to widen the rue Saint-Lazare in line with the Terminus Hotel. An arrangement has been considered by which the present footpath which is 4 m. (13 feet) wide would be reduced to a mere pathway, the roadway being enlarged 3 m. (10 feet). The movement of pedestrians would be partly provided for by the site now occupied by the café and the sales rooms of the Groceries Stores. The footpath would reach as far as the first interior row of columns, forming in this way a covered gallery similar to that running round the le Havre and Rome courtyards on each side of the hotel. This solution would, however, render the various rooms of the Café unusable, would cut across the principal entrance hall of the hotel and would seriously diminish the area of the Groceries Stores. Il would meet with very great opposition from the interested parties.

MONTPARNASSE STATION.

The Montparnasse Station has had for some years 10 tracks serving 8 passenger platforms — 4 set aside for main line (Brittany and the South West) service and the outer suburban (Chartres) trains, the other 4 for the suburban service (Versailles trains and the Clamart shuttle service).

This layout was notoriously inadequate. On the one hand, the short length of some of the platforms set aside for the main line trains (195 and 230 m. = 640 and 755 feet) made it necessary for many trains, both departure and arrival to be divided and part set into another platform.

On the other hand, the passenger traffic at Montparnasse has grown during the last twenty years to a considerable extent, from 7 600 000 to 13 millions, or an increase of 5 400 000 (71 %).

An annual increase of 5 % can be counted upon in the inner suburban area and 1.5 % in the outer. In addition, the opening of the Chartres via Gallardon line and the electrified Orsay line will result in an appreciable increase in the number of passengers. In particular, the suburban areas of Bagneux, Orsay, Limours, with a poor train service at the present time, and which by its picturesque character is destined to a rapid development as soon as it is better served, will certainly bring a very heavy additional passenger traffic.

From the point of view of train movement, the number of trains is made up as follows during a normal day :

Inner suburban. . .	129
Outer suburban. . .	11
Main lines	37
Or in all	177 trains per day.

To this must be added the movements of empty stock and locomotives, in number 286, as also movements due to shunting and running round certain suburban trains (66 movements).

On the other hand, the traffic is distributed very irregularly during the day. Two heavy passenger currents are noted — one towards Paris between 7 and 9 a. m., the other in the opposite direction between 5.30 and 7.30 p. m. In addition, at lunch time there is a considerable movement in both directions. The number of passengers at the busy hours reaches 5 100 suburban (6.15 to 7.15 p. m.) and 3 200 main line (8 to 9 p. m.) passengers.

During the summer service, Montparnasse has to overcome great difficulties in order to despatch between 8 and 10 p. m. several very heavy express trains carrying large number of passengers with considerable quantities of luggage. These trains have to be placed at the platform at least 45 minutes before the departure time.

It is not possible to despatch them at longer intervals as the public would not agree to a departure time earlier than 8 p. m., nor would it suit the public to leave after 10 p. m.

In addition, owing to the distance to be covered to get to the extreme end of Brittany and the Bordeaux region, La Rochelle, Royan, the arrival time the following morning would be too late if the departure time were later than 10 p. m.

The trains, moreover, are often run in two and even three parts.

In order to improve the position, a first step has been carried out. It consisted in transferring the handling of arriving main line trains to a provisional station built along the Avenues du Maine and de Vaugirard. This station is in fact the first section of a larger station which would deal solely with arriving and departing main line trains. The present station would then be used solely for suburban working; it would have 6 passenger lines — 4 under the main station roof set aside for the outer and inner suburban trains. These lines would be served by raised platforms 200 m. (656 feet) in length.

The main line station would have 14 lines with platforms 300 m. (984 feet) long and 5 to 7 m. (16 to 23 feet) wide. The roofed over platforms would be connected at their inner ends by a cross platform 17 m. (56 feet) wide covered in and adjacent to a building opening on to the Avenue du Maine and containing all departure services of the new station. The arrival side would be beside a courtyard running alongside the boulevard Vaugirard with a hall for dealing with luggage 130 m. (427 feet) long.

CONCLUSION.

It may therefore be expected that in the near future the different Paris stations will be provided with the necessary facilities to meet the constantly growing traffic they have to handle, especially as regards the suburban service.

From the point of view of this latter

one solution in particular has been under consideration namely to bring together under the control of a single Company the whole of the suburban services of the different systems. We do not think that such a solution will be found to be realisable as it would involve a considerable capital expenditure, a large increase in staff and a troublesome duality in the control of the great Paris stations in which the suburban and main lines are frequently called upon to help one another as best they may and at short notice, which can hardly be done except when the station is under a single authority.

[656 .253 (.73)]

Automatic train control systems on the Railways of the United States,

By A. KAMMERER, Berlin.

Figs. 1 to 9, pp. 293 to 301.

(*Elektrotechnische Zeitschrift.*)

Whereas in Germany the « Reichsbahn » proceeds on its own initiative with the development of automatic train control systems, the railway companies in the United States are required by law to introduce and maintain equipment of this kind on their main lines. By means of the technical and daily press German technical circles have already been given information at various times upon the work of this kind carried out by the Reichsbahn and private firms (1). On the other hand, however, very little information has been published upon the American equipment which has been devised to ensure, amongst other objects, that signals at danger are not run past. For this reason, we propose to give as complete as possible a review of the rationally designed methods employed up to date on the American railways. It is true that we cannot pretend to give a complete report on the question, seeing that the documents available rarely give technical details and still less theoretical considerations, and do not cover the whole of the systems (see table 1).

The Federal Commission called the « Interstate Commerce Commission » which in the United States is responsible for the supervision of the automatic train control systems supplied by industrial firms to the different railway companies has laid down the following definition of the « automatic train stop » or « train control » corresponding to our conception of the stop or automatic control of trains :

By this is to be understood, a system so arranged as to exercise automatically either one or the other, or both, of the following actions : 1. the automatic stop of the trains by causing an application of the brakes which shall continue until the train is brought to a stand; 2. the automatic control of the speed : in this case an automatic application of the brakes shall be caused when the speed of the train exceeds a certain predetermined value : the application of the brakes shall continue in this case until the speed of the train has been reduced below the said limit.

As a general rule, the Americans give the preference to the systems using electro-magnetic fields and which function, consequently, by electric induction; the experience of the American railway administrations is that this is the way in which the difficulties inherent to the profile of the track can be most easily overcome. Tests and applications have naturally been made with systems using electric or mechanical contacts, but these have not given favour-

(1) See *Elektrotechnische Zeitschrift* 1927, pp. 164, 1551 and 1555.

TABLE I.

Lines and locomotives equipped in virtue of the Orders of the Interstate Commerce Commission.

MANUFACTURER.	Intermittent control without speed control.		Continuous control without speed control.		Continuous control with speed control.	
	Length of lines equipped in kilometres (in miles).	Locomotives equipped.	Length of lines equipped in kilometres (in miles).	Locomotives equipped.	Length of lines equipped in kilometres (in miles).	Locomotives equipped.
In accordance with the first Order of the 13 June 1922.						
Union	1 105 (686.6)	310				
General	3 730 (2 317.7)	1 439				
Sprague	740 (459.8)	164				
National	601 (373.4)	290				
	6 176 3 837.6)	2 203				
Union	...	..	2 130 (1 323.5)	755		
General	...	...	...	...	480 (298.3)	122
Union	...	...	...	...	2 300 (1 429.2)	523
					2 780 (1 727.5)	645
In accordance with the second Order of the 14 January 1924.						
Union	88.7 (55.1)					
General	5 190 0 (3 225.5)	1 063				
Sprague	513.0 (318.7)	72				
National	908.0 (564.2)	204				
Miller	120.0 (74.6)	65				
	6 819.7 (4 237.6)	1 404				
Union	...	...	2 110 (1 311.1)	753		
Union	...	...	...	...	1 350 (838.8)	304
General	...	..	..	...	667 (414.4)	70
					2 017 (1 253.2)	374
Totals. . .	12 996 (7 548.0)	3 607	4 240 (2 634.6)	1 508	4 797 (2 980.7)	1 019

able results on the main lines, and notably so in regions where the climate is severe. To-day they have been abandoned in many cases in the United States of America; consequently the following notes will deal with systems based on electric induction alone.

I. — Continuous control.

The American railways use, even on the main lines, the automatic block system, with continuous or alternating current, to a considerable extent. On the sections so fitted, and in close connection therewith, certain inductive train control systems have been intalled. With these systems, the Americans are able to control, from a given point as it were, the trains whilst running. Alternating current circulating through the rails is used to incite the inductive coils — called receiver coils — suitably fitted to the locomotive. The German railways, not having the automatic block system on the main lines, are obliged to instal special « control points » which have to be distributed along the line according to certain predetermined ideas. Logically, the American systems mentioned above can be designated as « line controls » whereas the German systems are to be considered as « point controls ». The « point controls » are also found on the American lines to a considerable extent : they are used, for example, on lines not fitted with the automatic block system and are much the same as the German control systems.

As regards the conditions a good train control system should fulfil, the American Engineers are of opinion that it should ensure not only the automatic stopping of the train by the appliances in the permanent way, but further, on lines so equipped, should result in an increase in the traffic density and allow the trains to run with a greater degree of safety.

It was with a view to meeting this programme that there were developed on the sections of line equipped with the automatic block system the « line controls with speed control » which the Americans call « continuous control system ». Considered from the point of view of technical operation, this system consists in the trains being worked always in agreement with the signal indications and with the conditions existing on the line run over.

The driver, however, is not relieved of any part of his responsability, nor of any of the obligations of his duty. It is only in case of any failure on his part that the automatic control comes into action and either pulls up the train or reduces its speed to within the prescribed limit.

In the automatic block system, with continuous or alternating current, the rails are laid on wood sleepers so as to be insulated one from the other and from the earth. Similarly, the block sections concerned are rendered electrically independent one of the other at the joints of the rails by insulated fish plates. The system of continuous control presumes the presence of alternating currents flowing through the rails, currents already existing in part in the alternating current block-system, but which, in

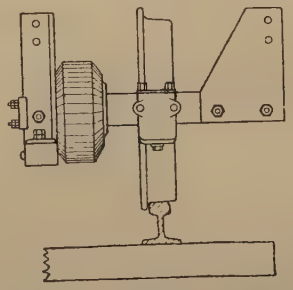

Fig. 1. — Receiver coil.

the case of the continuous current block system, have to be brought specially to suitably chosen points by being superimposed upon the continuous current. The currents flowing in the rails give rise

in their immediate neigbourhood to pulsating magnetic fields, which induce alternating currents in the « receiver coils » placed on the vehicle. The receivers are formed by laminated iron cores upon which the coils are fastened at a distance of about 150 mm. (5 29/32 inches) from the head of the rail (fig. 1).

The tension induced in the receiver coils is not sufficient to operate with certainty a relay of the normal type. For this reason provision is made for a two-stage voltage increaser which acts on a differential relay (fig. 2). The tension at the anodes of 350 volts continuous current for the voltage increaser is supplied by a small machine fed with current by the dynamo (32 volts) which supplies lighting current on the locomotive. This dynamo also supplies the current for heating the voltage increaser : with this object in view, two heater elements are arranged in series (16 volts heating tension). Iron resistances are used to maintain the heating current constant under variation in tension at the machine. The locomotive relay transmits the energy for the excitation of an elec-

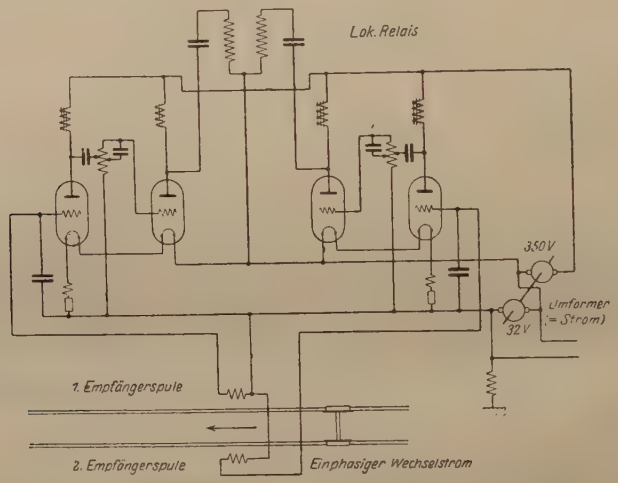

Fig. 2. — Voltage increaser for the two speeds system.

Explanation of German terms : Einphasiger Wechselstrom = Monophase alternating current. — Empfängerspule = Receiver coil. — Lok. Relais = Locomotive relay. — Umformer (= Strom) = Transformer (continuous current).

tro-magnet directly coupled to an air valve and known as the brake valve magnet. The relay actuates, in addition, an optical warning device placed in the engine cab, which indicates the maximum speed the train can run over the section of line in question. This indication is given by the illumination of lamps fitted on the driver's side. When no alternating current flows through the rails, the reduced speed indication is given or an automatic application of the brakes occurs under the action of the electro-magnet of the brake valve just mentioned. Arrangements are provided so that in the systems limiting the speed of the trains, the brakes are only applied automatically, independently of the speed, if the driver passes inadvertently the « braking points » near the

stop signal and has not realised his mistake within a certain time after so passing it. By braking point is to be understood the place where there occurs a change of the conditions of the current in the rails. It has the same significance as that which we have already called the control point. If the driver realises the danger in sufficient time, before the expiration of the before-mentioned interval, although in certain circumstances an automatic application of the brakes has occurred, the driver can release the brakes as soon as the speed has been reduced below the limit laid down. This speed limit is determined by the position of the sleeve of a centrifugal governor driven by special transmission through a worm, a helicoidal wheel and bevel wheels. For additional safety, a second auxiliary governor is used, the function of which is to cause the application of the brake when the principal governor or the auxiliary governor fails to do so. Ultimately, the point at which the automatic application of the brakes occurs after passing the braking point already mentioned depends upon the speed at the moment of running past this latter point. The interval after which the brakes begin to act is correspondingly longer as the speed is lower. With this object in view, special valves have been provided which are actuated by the governor at the same time as the automatic brake valve.

Systems with two and three series of speeds have been elaborated. The three-speeds system forms an extension of the two-speeds system and, moreover, contains all the characteristic features of the latter. It will sufficient then for the perfect understanding of the subject to examine closely one of the two. We will select the three-speeds system which the Americans themselves consider to be the more highly developed .

To receive and transmit three different signals, the relay in this system is constructed to give three positions of contact. With this end in view it has two windings. For the first indication, the currents flowing through the two windings have a mutual determined phase difference. For the transmission of the second indication, it is necessary to change the polarity of the current in one of the windings, and for the third indication one of the two windings must have no current flowing through it. The contacts fitted to the relay have, on the one hand, to bring into circuit the three lamps, green, orange and red, of the indicator in the engine cab, these three colours corresponding to the signals « line clear », « caution » and « stop » used in American signalling practice; on the other hand, the relay of the locomotive also actuates the air valves which come into action when reducing the speed. In this way it becomes possible to handle the train so that it cannot exceed the speed limits laid down for the section of line in question. If, for example, the maximum speed at which passenger trains can run under the three-speeds system in the section preceding the distant signal is 112 km. (70 miles) an hour, and if for goods trains it is fixed at 80 km. (50 miles) an hour, the speed limit corresponding to the middle section, that is to say, between the distant signal and the top signal, will be 72.5 km. (45 miles) an hour for the passenger trains, and 48.5 km. (30 miles) an hour for the goods. For the last section there is no speed difference between the passenger and goods trains; it applies to the block section following the stop signal, and is for both types of trains 32 km. (20 miles) an hour. The regulation of the control according to the class of train is in the hands of employees specially detailed for this duty.

In the three-speeds system, the section of line is provided with two track circuits (fig. 3) for transmitting the three indications. The first called « axle

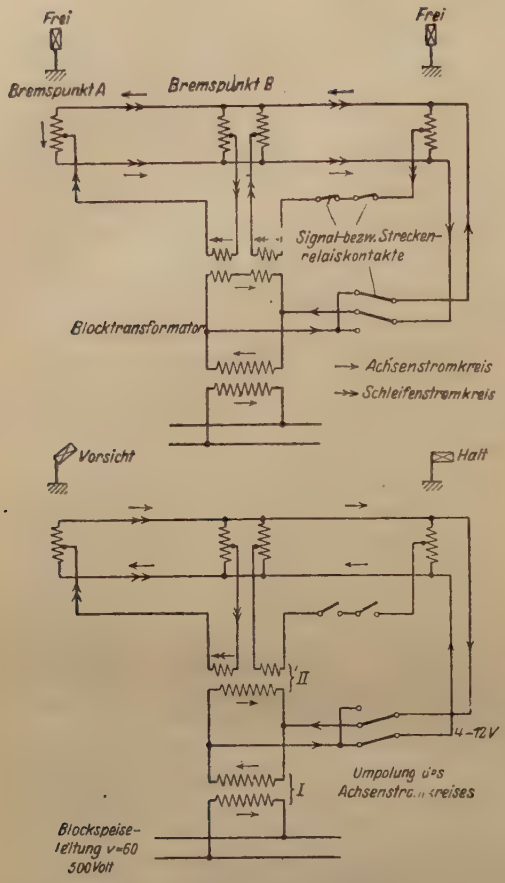

Fig. 3. — Track circuits for the three speeds system.

Explanation of German terms : Achsenstromkreis = Axle circuit. — Blockspeiseleitung = Supply line of the block section. — Blocktransformator = Transformer of the block section. — Bremspunkt = Braking point. — Frei = Line clear. — Halt = Stop. — Schleifenstromkreis = Loop circuit. — Signal-bezw. Streckenrelaiskontakte = Contacts of the signal or track relays. — Umpolung des Achsenstromkreises = Change of polarity of the axle circuit. — Vorsicht = Caution.

circuit » can have its polarity changed as required, and the second which is known as the « loop circuit » energised or de-energised. The « block section transformer » supplies energy for the two circuits : the current for the « axle circuit » is taken from the secondary of the transformer I, and that for the « loop circuit » between the braking points A and B, or for the circuit between B and the home signal from one of the two secondary windings of the transformer II. The current of the « axle circuit » circulates so long as there is no pair of wheels in the block section, through one rail, returning across the connectors of the reactances to the other rail and back to the source of supply. The current of the loop circuit flows towards the middle of the connectors of the reactances parallel to the rail, and returns to the connectors of the other reactances and to the source of supply. Figure 3 clearly shews the direction of flow of the current when the circuit is broken or the polarity changed. The currents are switched on or cut off by the contacts corresponding to the relays of the signals or of the track.

In the continuous three speeds systems, the locomotive is fitted with two pairs of receivers, one being placed at the leading end of the locomotive and the other at the trailing end of the tender. The leading end reception coils are connected in such a way that the electro-motive forces induced by the outwards and inwards current of the first circuit add together : the electromotive forces induced in the coils by the loop circuits (the currents of which flow in the same direction in the rails) are in opposition and consenquently neutralise one another. Furthermore, the beginnings and ends of the windings of the reception coils at the trailing end are connected together so that the electromotive forces of the second circuit add together. The sum of the electromotive forces of the leading reception coils excite a relay winding, that of the trailing reception coils the other relay winding.

In order to transmit the second indication, the axle circuit, and consequently also the current in the first winding,

have their polarity changed. If one of the said circuits or the two are without current, the third position of the relays is obtained. Figure 4 shews separately

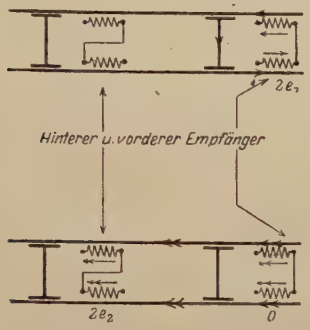

Fig. 4. — Fitting of the coils on the locomotive for the three speeds system.

Explanation of German terms : Hinterer u. vorderer. Empfänger = Leading and trailing receivers.

the tensions induced in the reception coils by the axle current and by the current in the loop circuits. Finally, figure 5 shews the grouping of the

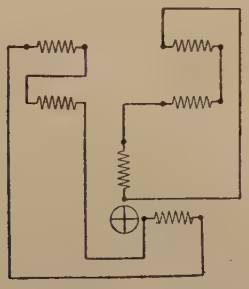

Fig. 5. — Two-phase receiver coils and locomotive relays.

reception coils with the two-phase relay (Ferraris disc relay). For the sake of simplicity the voltage increaser between the receiver and the relay has been omitted.

We will illustrate by a practical example the sequence of events during the control of the trains on lines having three limiting speeds such as we have just considered. We are unable to give a description of the construction of the pneumatic devices : it will be sufficient if we explain the manner of working of the equipment as a whole Where a train runs into a zone equipped with automatic control on the continuous system — this point is marked by an indicator post or some other sign — if the line is clear the green light in the engine cab lights up. So long as the maximum speed is not reached, the train can continue its journey without interference.

Let us now suppose that the train then goes forward at the same speed and during its journey runs on to a slight down gradient which causes it to exceed the maximum speed. The apparatus then acts and the speed of the train is brought below the limit. The driver releases the brakes by hand and continues his journey at a lower speed which leaves him sufficient margin. Let us suppose that after having passed another section, the train overtakes a preceding train. In this case it finds the next signal either at caution or danger. When passing this point, the indication given in the engine cab changes and gives an orange light instead of green, which calls the driver's attention to the fact that he must run at the intermediate speed. The driver shews that his attention has been aroused by, immediately after passing the signal (braking point A), moving the lever of the acknowledging valve, and by reducing at the same time the speed of the train to the prescribed figure. He can thereby avoid the automatic application of the brake. The train proceeds until it has reached the braking point B' before the next signal which is at danger (see also figure 3). This point is at such a distance from the next signal that, the control occurring at the braking point B, the train stops definitely short of reaching the stop signal. When B is

passed, the red lamp lights up in the driver's cab, which means that from then on the train can be run at the lowest of the three speeds only. Here again the driver must act as in the first case if he wishes to avoid an automatic application of the brakes. He can also run into the occupied block section, but only when running at the lowest speed and looking out for the preceding train. Furthermore, the indication given in the cab would be, instead of a red light, a green light if, for example, the preceding train was turned for any reason whatever into a siding and consequently cleared the main line. The driver would then obviously be able to continue his journey at the highest speed. If he forgot, on arriving at the braking point B of a stop signal, to operate the acknowledging valve lever, the automatic application of the brakes would take place even if the train were running at a speed lower than the minimum in force at the place. The brakes can only be released after 40 seconds. In the same way, in case of a rail breaking or if the rails for any cause whatever were connected together electrically, the breaking or short circuiting of the circuits in question would at once cause an automatic application of the brakes. It should be noted in this connection that when the brake is applied automatically it is not applied with any greater force than under ordinary service applications. In the case considered above, the driver will also make, in addition, a full application by hand. By virtue of the principles upon which the continuous control system is based, the train can run past the danger point at the lowest speed free to accelerate subsequently to the extent permitted by the state of the section ahead.

If, for any reason, the driver observes that the control equipment fitted to the engine is not working properly, he can cut out the pneumatic part by opening a special valve normally sealed in the closed position. If the defect only affects the pneumatic part of the installation, there would always remain the cab signals to act as a control for the driver.

The two speeds system, from which the three-speeds system was developed, has not at all the same flexibility as the latter. To the two speeds there are in the driver's cab only two corresponding signals, a green and a red. The section between the distant and the home signal can be run through at full speed, and that after the home signal at reduced speed. Here again the braking point is placed at an adequate distance from the principal signal. In the case of lines equipped with the block system utilising continuous current, use is made of a single pair of receivers only (fig. 2). But with the automatic block supplied with alternating current, it is necessary to use, as with the three-speed system, two pairs of receivers. Changing the polarity of one of the alternating current circuits then becomes useless since only two positions of the relays are needed.

Automatic train control systems with limiting speeds are mainly installed in America by the two firms, the Union Switch & Signal Company and the General Railway Signal Company. The two methods of construction only differ in important features in that the limitation of speed behind the governor takes place in one case pneumatically, and in the other by electric contacts operated mechanically. The description given above applies principally to the Union Switch & Signal Company's system.

The same Company has brought out another design which differs to a great extent from the arrangements described above : it has no speed governor and can, it is said, be equally well used on steam and electric railways : only the indications given in the driver's cab have been retained. These indications, moreover, are not produced by continuous current, but by alternating currents interrupted in

a pre-determined order of sequence (*code system*). These alternating currents also circulate as in the preceding case, through the track circuits. Each of the periods of interruption just mentioned corresponds to a special indication in the driver's cab. When the train runs into the first block section of a series of which the last is occupied, the electric connection established by the wheels and axles of the vehicles form between the two rails a circuit in which is inserted a small induction motor. This motor actuates by means of gearing the contacts of interrupters which produce the sectioning of the alternating current circulating in the rails. It is in this way, for example, in one system installed that the currents are interrupted either 180 or 120 or 80 or zero times a minute, and are picked up on the locomotive by suitable selector relays in order to be employed to give the signal indications as in the systems considered above. In order to avoid the disturbances set up by the lighting and power mains (60 and 25 periods), in this system the frequency of 100 is used to transmit the signals. The delay allowed to the driver to operate the acknowledging valve lever is in this case 6 seconds. During this time a warning whistle also acts to more definitely attract the driver's attention. If the train is stopped by an automatic brake application, the driver cannot start it again without getting down from his engine and pressing a stud placed under the cab. With the system just described, the driver equally retains his full liberty of action, that is to say, he can use his driver's brake application valve as in normal service.

II. — Intermittent control.

We have noted at the beginning of this article that in the United States of America the intermittent control systems are also used to a considerable extent. In the continuous system, the energy required for the control of the trains is principally supplied through the rails, whereas the energy supplied by the turbo-electric set supplying lighting current on the locomotive is only used for the high voltage. With the intermittent control system, on the contrary, all the electric energy required is supplied by the electric light equipment of the locomotive. The intermittent controls are divided in turn into two groups, according as they use continuous or alternating current. In the first case, the turbo-generator of the locomotive supplies the current : in the latter a small alternator is directly coupled to the turbine and supplies the alternating current needed.

In the continuous current system at a suitably chosen position on the engine outside the track, a transmission device generally U in shape, the essential part being a core of iron laminations, is fitted. This core carries two windings, the first of which is used to excite the magnetic field needed for the control of the train, whilst the second winding (the receiver) is intended to pick up the impulses. The two windings are arranged in parallel with the continuous current dynamo of the turbo-generator on the locomotive. In the secondary circuit, there is also a continuous current relay and a regulating resistance. Along the line there are also installed in accordance with the character of the intermittent control, cores of iron laminations to which the name of « inductances » is given. Each inductance consists, like the electro-magnet on the locomotive, of a core formed of transformer plates with a winding. The winding of the inductance can be in open circuit or short circuited by contacts which control either the signals or the track relays of the automatic block system (see fig. 6).

The whole assembly is so arranged that in the normal position, that is to say, when running over a clear line, the armature of the relay is attracted. When the locomotive runs past an inductance set to the stop position by breaking the

winding circuit, the magnetic conductivity of the circuit is built up and by this, during the passage of the locomotive, there is induced in the receiver win-

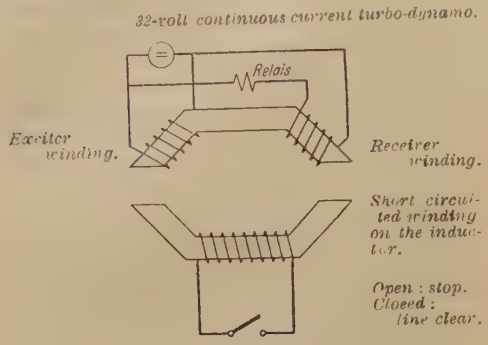

Fig. 6. — Continuous current control.

ding a counter-electromotive force which has for consequence such a weakening of the current in the receiver winding that the armature of the relay falls. In the position of line clear, on the other hand, the winding is short circuited which results in the armature remaining in the attracted position. Beyond the already mentioned relay, two other relays are fitted, the controls of the last of which operate the electro-magnet of the brake valve. In order to avoid the use of a voltage increaser and to obtain when running past the control point, as strong variations of current as possible or, in other words, to get unfavourable coupling conditions, it is essential that the air gap, that is, the free space between the iron core on the vehicle and that of the inductance, should be as small as possible (3.5 to 4 cm. 1 $^{3}/_{8}$ to 1 $^{9}/_{16}$ inches). Frequently, in the continuous current systems, the receiver is fastened to a tender axle box, that is to say, to an unsprung part of the vehicle.

As a typical example of an intermittent control system using alternating currents, the system developed by the « Miller Train Control Corporation » will be described here. The locomotive carries, on the side away from the six foot, a receiver consisting in essentials of two cores built up of iron laminations. In the original type these two iron cores were placed one above the other in the form of an X : one of the two windings acting as exciter, the other as receiver. In the circuit of the latter there is a monophase current electro-magnet which directly operates a pneumatic valve which starts the automatic brake action should it be necessary. In the most recent design, the two iron cores are placed in parallel side by side. The exciter winding is now so arranged that half is carried by one core and the other half by the other core. The same arrangement is followed in the receiver circuit. Owing to this arrangement the magnetic flux is obliged to cross, between the two cores, four air spaces in all, and thereby better coupling conditions are ensured. The line inductors also consist of two laminated cores which are, in both designs, placed in parallel side by side. They are fitted with windings which should be on open circuit for the stop position and closed for line clear. To compensate for the dispersion of tension, condensers are inserted in the circuits. Under the normal condition, that is to say, running over a clear line, the current engendered in the receiver circuit by the transformer effect which occurs between the exciter circuit and the receiver circuit is so powerful that the armature af the electro-magnet is held with sufficient security, but if the train passes over an inductor at the stop position, the magnetic flux suddenly finds another path before it with the result that the current in the receiver circuit changes direction or falls to zero. The consequence of this is that the armature of the electro-magnet falls and the automatic valve opens. If the ends of the windings of the inductor are connected together, the effect on the receiver circuit is so slight that the armature remains attracted. In this manner, the

inductor is maintained in the braking position (see figs. 7 and 8). If an automatic brake application has taken place, the release — as we have already

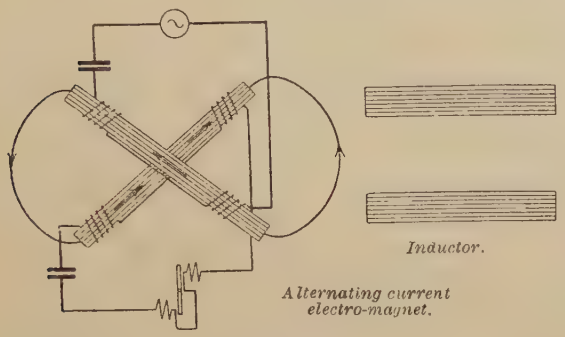

Fig. 7. — Alternating current control, old system.

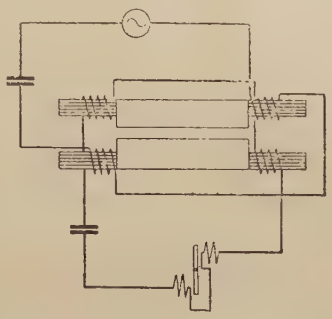

Fig. 8. — Alternating current control, new system.

mentioned above — cannot be effected until after the train has been brought to a stand. With this object, the Miller system includes a centrifugal liquid contact which only closes the circuit when the number of revolutions has fallen to zero. The liquid in the contact is mercury. As a result, the driver need not get down

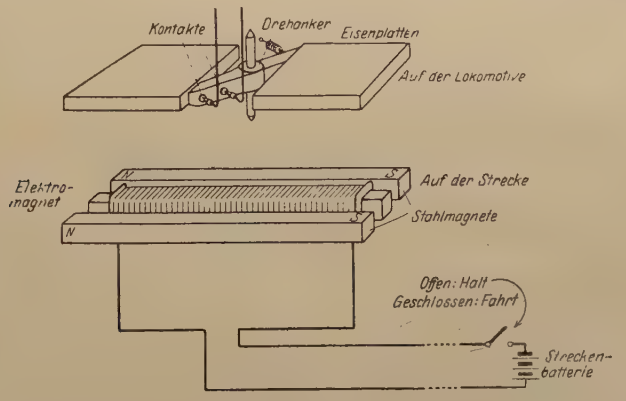

Fig. 9. — System with excitation by means of permanent magnets.

Explanation of German terms : Auf der Locomotive= On the locomotive. — Auf der Strecke = On the track. — Drehanker = Turning armature. — Eisenplatten = Iron plates. — Elektromagnet = Electromagnet. — Kontakte = Contacts. — Stahlmagnete = Permanent magnets. Streckenbatterie = Track battery.

from his engine to be able to restart after a stop : all he has to do is to turn a switch in the cab. In the system just described the power absorbed is, from published figures, about 90 volt-amperes at a frequency of 560 periods and 32 volts tension.

Lastly, a word must be said about a

system (the Sprague) which also belongs to the category of intermittent control systems, but which differs from the others by making use of permanent magnets to excite the different devices. In principle, the system is arranged as follows : in the track between the two rails, the control points are formed, as has just been said, by permanent magnets. Each control point consists of ten bars assembled in two groups of five each, between which an electro-magnet is located. When the control acts, the exciting current of the electro-magnet is interrupted by the contacts of the signal relays or, according to the case, of the track relays, so that the field of the permanent magnets can also develop in an upwards direction, that is to say, from the side nearer to the vehicle. The receiver fitted on the locomotive consists of two iron plates arranged in the same plane, with the lower faces about 115 to 140 mm. (4 17/32 to 5 1/2 inches) from the top of the rail. These are fitted into a holder of non-magnetisable material at a certain distance apart (fig. 9). In the air gap separating them is a rotatable armature in iron, the springs of which bear against an electric contact. When the control acts, the magnetic flux starting from the permanent magnets has the effect that the armature which, under normal conditions, has a little play between it and the ends of the plates, bears against these latter, and in this way opens the contact which, in its turn, stops the excitation of the electro-magnetic relays and thereby starts the application of the brake.

It should be noted that all the automatic train stop systems described in this article are based on the closed circuit principle. This is a point upon which stress is always laid in all American descriptive articles.

CURRENT PRACTICE.

[625 .4 (.42) & 656 .211 (.42)]

I. — The new Piccadilly Circus Station.

Figs. 1 to 4, pp. 305 to 310.

(From the *Railway Gazette.*)

The completion of this new station marks not only an important improvement in « Underground » facilities, but an important addition to the public amenities of Westminster, as the scheme includes a system of public subways beneath the traffic-congested Circus and a special subway for the pipes and cables of public-service undertakings. The task of construction, which has occupied about four years, is a noteworthy engineering achievement, the more so as it was accomplished without interference to surface traffic or disturbance to « Underground » services. The station itself is an interesting departure in railway station architecture and is notable for various innovations in railway practice. The entire cost of the new works — over £ 500 000 — is being borne by the « Underground » companies.

The original station at Piccadilly Circus dates from 1906, when the « Bakerloo » and the « Piccadilly » tubes, which cross each other here, were opened. It was designed to serve both lines, and in the light of the traffic of the period the station seemed adequate to meet requirements for many years to come. The development of the Piccadilly Circus district (development stimulated by the tubes) was so rapid, however, that even before the war the pressure of increasing traffic taxed the capacity of the station.

Various improvements were effected. Structural peculiarities and other exigencies, however, debarred the installation of escalators and the provision of a really commodious booking-hall, and attention was consequently given to the construction of a new station as the only satisfactory scheme. It was decided to follow the plan that had been adopted at the Bank and to build a station beneath the open space of the Circus, west of the existing station.

When first opened, Piccadilly Circus station had to deal with an annual traffic of 1 1/2 million passengers; to-day the figure is 25 millions, or an average yearly increase of over one million passengers. About 1 600 trains now serve this station daily.

Engineering problems involved.

To appreciate the difficulties that confronted the engineer and which have been successfully surmounted at Piccadilly Circus, it is necessary to understand fully the peculiarities of the site and the respective situations of the two railways.

The two railways lie at different levels. The « Piccadilly » tube is 102 feet below the surface : the « Bakerloo » tube was the first of the two lines to be constructed and is 86 feet below the surface.

The task to be accomplished comprised

the construction of a spacious booking-hall only a few feet below the roadways, with subways radiating from it to the various streets around the Circus; a lower hall, 42 feet beneath the booking-hall and connected with it by five escalators; and between the lower hall and the two railways below it — at different levels! — further flights of escalators and the stairways and passages to connect them with the platforms. Certain short passages had to be formed to improve the interchange traffic connections of the two railways.

Practically all of this involved task had to be conducted without opening the roadways, without interfering with traffic, and without disturbing the services supplied by the gas, electric light, telephone, water, and hydraulic-power mains running in all directions immediately beneath the roadways. To complicate the problem further, a large sewer passed right through the site of the booking-hall.

Construction began in February 1925, with the sinking of the service shaft from which the excavation was to be carried out. The only site available was the small island on which the Shaftesbury Memorial stood, and this had of necessity to be removed. On the site of the memorial a shaft 18 feet in diameter and 92 feet in depth was sunk, and from this the construction of the new works, with the exception of the booking-hall, has been carried out. The shaft has been used also for the passage of material, plant, etc., to and from the works; for bringing spoil up to the surface — during excavation a thousand tons of clay were brought up monthly — and in it is now the emergency staircase of the new station. The island on which the shaft was sunk represents probably the smallest area that has ever been used for this purpose, which means that the space available for the erection of gantries and gear and for the storage of material, etc., was correspondingly limited.

General constructional methods.

Having sunk the shaft, the next procedure was to drive headings, or tunnels, at various depths. From headings in the lower part of the shaft the construction of the stairways, passages, etc., to connect the lower flights of escalators with the respective platforms of the two « tubes » was put in hand. From headings in the middle of the shaft the work of forming the lower hall of the new station and of driving the inclined tunnels for the lower flights of escalators proceeded.

Before the construction of the booking-hall and the public subways in the upper levels could begin, it was necessary to prepare a special subway to carry a duplication of the water, electric light, and other mains that formed a tangled skein below the roadways. These mains could not, of course, be disturbed until measures had been taken to ensure the continuance of the various services.

This pipe subway, as it is termed, is remarkable in being the first of the type to be constructed in this country, with the qualification that the first tube ever constructed — the old Tower Subway, the prototype of all iron-lined tunnels — is now adapted to a similar purpose.

The pipe subway at Piccadilly Circus is 12 feet in diameter, or 3 3/4 inches larger than the running-tunnels of the Tube railways. It is of similar design, being of circular section and lined with cast-iron segments.

Cables and pipes alike are thus readily accessible, and henceforth any work concerned with them can be conducted without the former necessity of opening roadways.

This part of the work, with other sections, received attention in the 23 December 1927 issue of *The Railway Gazette*.

Constructing the booking hall.

The construction of the booking-hall was achieved by means of a series of

Fig. 1. — The new Underground station at Piccadilly Circus.

burrowings, until the ground beneath the Circus became a labyrinth of steel-roofed and steel-supported tunnels, which, eventually, through the removal of the intervening walls of earth, became merged into an elliptical chamber 155 feet by 144 feet in area and 9 feet in height, only a few feet below the surface.

Each of the four columns erected in the central portion of the hall is capable of supporting a weight of 309 tons; whilst the fifty columns erected in a double row around the perimeter of the hall are capable of supporting individual loads ranging from 78 to 150 tons.

The steelwork that supports the roadways above the booking-hall has been likened to a breastplate. Before the work of installing began, the breastplate was fitted together in a yard at Josiah Westwood & Co.'s works, and every piece numbered in conformity with its position shown on the engineer's plan.

Engineering procedure.

The procedure was as follows : Near the service shaft two circular cavities were made in the ground, and from these, headings, 8 feet wide and 6 feet in height, were driven for about 40 feet. As the tunnelling proceeded, the ground above was supported by rolled-steel joists that were to be the permanent roof-joists of the booking hall. The next detail was to form a hole at each end of the headings and to lay in these holes the foundations for the main columns to support the central portion of the booking hall. These four columns having been erected, the main girders of the roof were brought into the headings and placed upon them. The weight of the ground above the headings, hitherto supported by temporary timbers placed in position as the headings were driven forward, was then transferred to the main girders by the insertion of steel packings between the latter and the roof-joists. Numerous other headings were then driven for the introduction of the columns and the main mid-level of the station, consists of four and secondary girders to sustain the weight of the ground above the other parts of the booking hall.

Concurrently with driving the headings for the insertion of the steelwork, another heading was driven right around the perimeter of the site, and in this the concrete and brick foundation of the wall that was to enclose the booking hall was built. Next, a second heading was driven along the top of the brickwork built within the first heading, and in this the brickwork was brought up to the second stage. The wall was completed through the medium of certain of the headings formed for the insertion of the steelwork.

Subways.

The six subways that radiate from the booking-hall were excavated by methods similar to those adopted in constructing the booking-hall. The subways connect the booking-hall with the following points around the Circus : Swan & Edgar's corner (two entrances), the County Fire Office corner of Regent Street, the Pavilion corner of Shaftesbury Avenue, the old « Underground » station, and each side of Lower Regent Street. A subway has been built below the last-named street, connecting the two entrances here and thus providing a direct crossing beneath this congested « one-way traffic » thoroughfare. Through the medium of the ambulatory encircling the booking-hall the subways as a whole afford a means of communication to and from all sides of the Circus.

The escalators.

Owing to the depth of the platforms below the surface it was necessary to divide the escalators into upper and lower flights, the former connecting with the lower hall, whence the latter strike off in a reverse direction and terminate close to the platforms of the respective tube

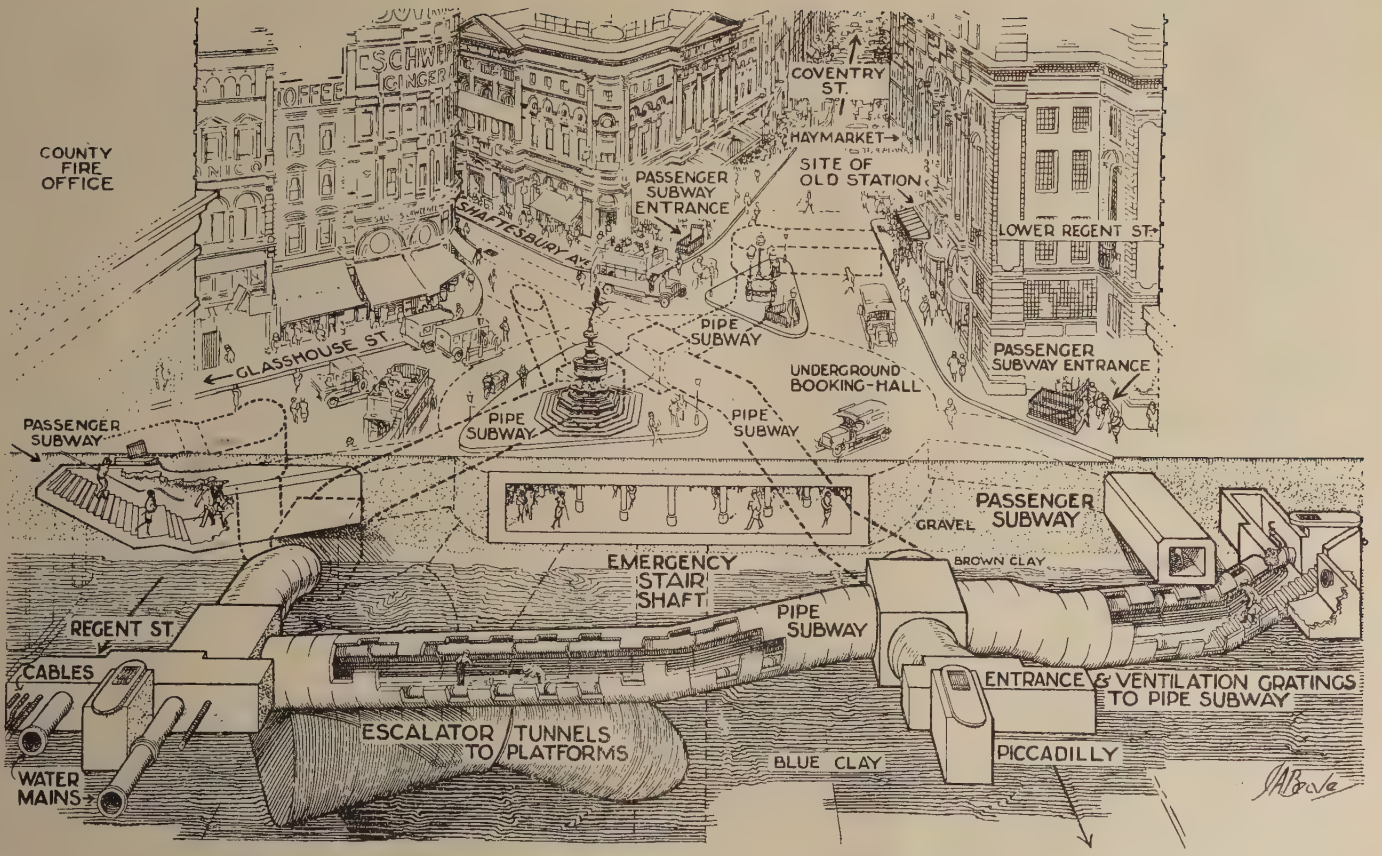

Fig. 2. — Diagrammatic view showing pipe subway and connections.

that they serve. The lower hall, in the mid-level of the station, consists of four arched bays, and is 90 feet long by 32 feet wide.

In all there are 11 escalators, the greatest number at any « Underground » station; and the five of the upper flights are the largest number yet installed side by side. All the escalators are adapted to being worked in either direction.

The upper flights of escalators comprise two and three, respectively, in parallel tunnels running down from the north side of the booking-hall. The inclined tunnels, which are 60 feet long, were driven from the booking-hall. The one containing the two escalators is 16 ft. 4 in. in diameter; the one containing the three is 22 ft. 4 in. in diameter.

The lower flights comprise two triple sets, to left and right, respectively, of the lower hall. The set on the left, which connect with the « Piccadilly » tube, are in an inclined tunnel 63 feet in length, and have a fall of 39 feet; whilst the set on the right, connecting with the « Bakerloo » tube, are in a tunnel 26 feet in length and have a fall of 21 feet. The diameter of the tunnels is 22 ft. 4 in. in each case.

All the escalators are of the Otis Elevator Company's improved cleat-comb type, with a speed of 100 feet per minute. Each escalator of the upper flights is operated by a 45-H.P. electric motor; those of the lower flights by 35-H.P. motors. These motors are contained in chambers in the upper part of the escalators. By the depression of a button a moving escalator can be at once brought to a standstill in cases of emergency.

Work statistics.

The whole of the excavation work was carried out by hand. Special measures were adopted to render the various tunnels, etc., watertight. The joints between the cast-iron segments lining the escalator tunnels and the public and the pipe subways were caulked and filled in with concrete, after which the surface was finished off with a thin coat of Castor waterproof cement plastering. The latter form of finishing was adopted also for the booking-hall. In all, an average of about 150 men were constantly engaged during the four years or so occupied in the construction of the station and its appurtenant works.

Among the more important items of material used were 950 tons of steel girders, etc., 2 700 tons of cast-iron segments, 3 600 tons of cement, and 1 1/4 million bricks. These represent some of the materials put in. The material taken out aggregated 34 000 cubic yards of London clay and other geological constituents.

As the cost of material is composed chiefly of the cost of labour employed in its preparation, it may be said that the £ 500 000 expended on the new station has been instrumental in providing employment not only beneath Piccadilly Circus, but in various other parts of the country.

The ambulatory.

The space between the two rows of columns that are the dominating architectural and structural feature of the booking-hall has been adapted to the purpose of an ambulatory. This passes right around the hall, enclosing the head-wall of the escalators and an inner circulating area, and is open to both passengers to and from the « Underground » and the general public using the subways to cross the Circus. The columns are covered with red scagiola, relieved by narrow vertical fillets of bronze, and have bronze bases and caps. From the cap of each column two lights, enclosed by opal cylindrical shades, are suspended. The columns in the central portion of the hall have been similarly treated.

The show cases, which flank the outer side of the ambulatory on the north, east and west, and screen the retaining wall, are of bronze, with frieze and skirting of Travertine marble. The show cases are

lighted by concealed lamps. The booking office, on the west side of the ambulatory, is likewise of Travertine marble and bronze, whilst the telephone cabinets on the south are of polished teak.

Architectural and decorative features.

At the rear of the head-wall of the escalators is a row of five stalls in Travertine marble and bronze. The continuity of the show cases, telephone cabinets, etc., that flank the outer verge of the ambulatory is broken at intervals by the openings of the public subways. The subway on the west — connecting with Swan & Edgar's corner of the Quadrant — is 20 feet wide, and is flanked on each side by show cases. This may be termed the grand entrance to the station.

The floor of the booking-hall is paved with large white tiles, a foot square; whilst the ceiling of white fibrous plaster is divided into rectangular coffers. To preserve the harmony of design and the colour scheme, the special ticket machines that will be installed later will be encased in Travertine marble.

Above the escalators, on the inner sides of the head-wall, are paintings in oil by Mr. Stephen Bone. The central compartment contains a map of the world, showing the British Empire in a distinctive colour, with the names of the capitals of the various Dominions and Colonies inscribed. Flanking the map are to be smaller panels with pictures representing the activities of the « Underground » in the sphere of urban and suburban transport.

The lower hall has the walls tiled in a groundwork of silver-grey with mauve borders, divided into poster-panels edged with blue. The upper parts of the walls and the arches are in white matt distemper. Lighting is by concealed lamps.

The escalators have the standard form of polished teak balustrades, and the advertisement frames on each side are of similar wood. The arches of the tunnels are finished in white matt distemper. Lighting is by means of bronze pedestal lamps, set at intervals along the decking of the balustrades. Special shades direct the light upwards and cause it to be diffused with uniform softness, so that there is no glare.

Apart from the ever-open access they provide to and from the platforms, the escalators, compared with the lifts of the old station, have the further advantage of abutting in close proximity to the platforms, which are situated directly below the Circus. Owing to the old station being in line with the building frontage at the eastern extremity of Piccadilly, a walk of some little distance was necessary in passing between lifts and platforms. The time occupied by passengers in passing from street to platform, and *vice versa*, at the new station will be equal to a saving of 2 1/2 minutes compared with the time taken at the old station.

The tiling of the public subways is of biscuit colour, relieved by black borders, and with similar borders for the poster-panels. A brilliant yet soft lighting is effected by means of electric lamps having opal shades. The staircase heads are enclosed by bronze railings of artistic design, surmounted by illuminated signs bearing the words, « Underground : Public Subway ». At the foot of the staircases connecting with the street are collapsible gates. The subways are open throughout the hours of traffic on the « Underground », *i. e.*, from 5.30 a.m. till 12.50 a.m. on week-days, and from 8.0 a.m. till 11.30 p.m. on Sundays.

Booking equipment.

In conformity with modern « Underground » practice, automatic machines will play an important part in the booking arrangements at the new station For the present the machines are of the standard electric type, delivering pre-printed tickets, but these will be replaced by a battery of special A.E.G. ticket printing and delivering machines.

Fig. 3. - The island site from which all work was done.

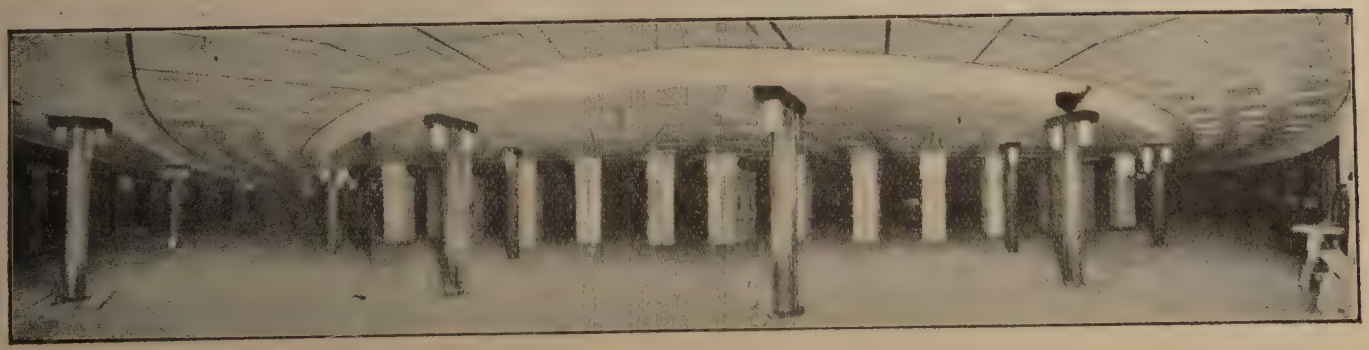

Fig. 4. View of circulating area showing supporting columns, ticket machines, etc.

The first installation comprises 26 machines, arranged so that they form portals to the passenger circulating area, or inner ring, of the booking-hall. They issue tickets ranging from 1d. to 6d. in denominations, and consist of two machines for 1d. tickets, two for 1 1/2 d., eight for 2d., eight for 3d., four for 4d., one for 5d., and one for 6d. Tickets of denominations above 6d., season tickets, and other kinds not adapted to machine delivery will be obtained at the auxiliary booking office, which will be equipped with three A.E.G. ticket printing and issuing machines. For the convenience of passengers using the automatic machines, a change-giving kiosk is provided. Near the escalators is an inquiry kiosk.

A set of train-recording clocks is provided, on the dials of which are automatically recorded the working of the services of the six railways of the « Underground ». By means of electrical connections between the clocks and the track at certain stations, the passing of a train is recorded on the dial by an inked pointer. The regularity of the strokes indicates that the various services are working normally. The clocks record the passage of trains at the following points on the « Underground » system : Piccadilly Circus (Bakerloo line), Leicester Square (Piccadilly and the Hampstead lines), Tottenham Court Road (Central London Railway), Kennington (City line), and St. James's Park (District Railway).

The architectural scheme adopted may be regarded as the free application of modern ideas to special conditions. It is unconventional. The spacious area, elliptical plan, and low pitch of the booking hall (it is only 9 feet in height) with its double row of columns, and the encircling range of show cases and telephone cabinets, militated against a treatment on classical lines. No attempt has been made to follow any particular style, with the result that a composition that is both original and effective has been produced.

Opening by the Mayor of Westminster.

Always a lively centre, Piccadilly Circus early on 10 December 1928 afternoon was even more animated than usual owing to the eagerness of the general public to make themselves acquainted with the engineering marvels of the new « Underground » station of which so much has been heard lately, and generous references to which had appeared in that morning's papers. Crowds collected at the various subway entrances long before the advertised hour of admittance, but the police on guard there were inexorable, and it was not until three o'clock that Londoners in general had the opportunity of « sampling » a structure which has already been described, on expert authority, as not only the finest underground station in London, but also in the whole world.

It was known in London that the new station was to be officially and formally opened by Major Vivian B. Rogers, D.S. O., M.C., J.P., Mayor of Westminster, and in anticipation of that happy event a large and distinguished company began to assemble, shortly after 11 o'clock in the forenoon, in the spacious concourse immediately beneath the Circus. A brief preliminary inspection before the arrival of the Mayor speedily confirmed the good impressions that one had gained from the published newspaper descriptions of the new station — the outstanding impression probably being that of brightness, the result of some wonderful system of lighting, and a gracious warmth. Later on, of course, the company had the opportunity of a more leisurely and extended tour.

Shortly before half-past eleven the Mayor of Westminster arrived at the station, and was met by Lord Ashfield (Chairman of the « Underground » group of companies), Mr. Charles Holden (Consulting Architect), Mr. Arthur R. Cooper (Chief Engineer of the « Underground » Company), Mr. H. H. Dalrymple-Hay (Consulting Engineer), and Mr. G. Burt

(representing John Mowlem Limited, principal contractors). A move was made towards a reserved space near the escalators, where was placed a decorative electric lamp mounted on a pedestal.

Lord Ashfield, in welcoming the Mayor, made graceful reference to the co-operation his group had received from various public bodies whereby the construction of the station in which they were assembled had been rendered possible. It might be suggested that they had been rather generous, perhaps even luxurious, in providing that new facility, but circumstances warranted it. Since the old station was opened in 1906 the traffic had grown from 1 500 000 passengers a year to something approaching 25 000 000. It was their duty and responsibility, not alone to review the problem as it existed, but also to visualise as best they could what was going to happen in the years to come. If they were successfull, as he thought they would be, in obtaining the same measure of co-operation from public bodies as they had received in the past, he thought they would see in the immediate future a very considerable extension of the present system of underground railways. An extension northward was badly needed, as well as an extension westward towards Hammersmith. That would mean a large increase of passengers everywhere in Central London, of which Piccadilly was the centre. There was also a perceptible drift of passengers from the surface forms of transport to the « Underground » railways — due not only to the rapidity of the latter, but also to the increasing congestion of the main streets. For these reasons the new station had been designed to bandle 50 000 000 passengers a year and considerably more if circumstances warranted it. He claimed that the new Piccadilly Circus station was not only the best underground station in London, but the best in the world, and would challenge comparison with any similar station in New York. It had cost £550 000 to build — part of the £13 000 000 which the « Underground » undertaking had been able to raise on satisfactory terms by the aid of the Trades Facilities Committee.

The Mayor of Westminster, in a brief speech, declared the station open, at the same time switching on the electric lamp aforesaid and simultaneously starting the 11 escalators which serve the station. The party then descended by means of the escalators to the lower station and made an extended tour of inspection. Incidentally and *en route* the Mayor of Westminster purchased the first 2d. ticket (specially printed for the occasion on ivory and retained as a souvenir) from one of the automatic machines.

[625 .4 (.42 + .44)]

2. — Proposed London and Paris Railway.

Fig. 1, p. 314.

(*The Railway Gazette.*)

For some time past a scheme for the construction of an entirely new railway between London and Paris, running through a twin tunnel under the Channel, has been in preparation, and is now made public in the form of a volume of nearly 300 pages, entitled, *Proposed London and Paris Railway : London and Paris in 2 hours 45 minutes,* by William Collard (London : P. S. King & Son, Orchard House, Westminster. Price 10 s. 6 d.), who, it is understood, has devoted many years to the study of the project.

Outline of the scheme.

The scheme contemplates the construction of an entirely new broad-gauge (7-foot) electric railway, capable of accommodating trains of a gross weight of 550 tons. Haulage would be by means of electric locomotives at a maximum speed of 120 miles per hour, which would accomplish the journey in 2 hours 45 minutes, an average of 92 miles per hour. The new railway would be 253 miles long.

The London terminus would be in the Horseferry Road district of Westminster, at an altitude of 56 feet above sea-level. The railway would cross the Thames by a new bridge at the same level, and would then rise at 1 in 750 for 21½ miles, passing Peckham, Lewisham, Sidcup, Farningham, Fawkham Green and Ridley, and would fall at 1 in 880 for 7½ miles through Trottiscliffe, Addington and Leybourne. A level stretch of 3½ miles would bring the line to Maidstone. From Maidstone the railway would go up the Len Valley, with stations at Bearsted, Leeds Castle and Harrietsham, through Chilston Tunnel, Chilston, Little Chart, Hathfield, Ashford, Willesborough and Brabourne, and Monk's Horton station.

At this point, falling 1 in 165, the railway would enter the 11-mile approach to the Channel Tunnel proper. The tunnel proper would be nearly 24 miles in length, according to the plans already known, and the exit on the French side (at a gradient of 1 in 185), 9 miles in length, making 44 miles in all. On leaving the tunnel section the railway would pass near Ambleteuse, Wimereux, Boulogne, Montreuil-sur-Mer, Amiens, the Valley of the Noye, with stations at Ailly-sur-Noye, La Faloise, and Breteuil. After passing through the Noyers St. Martin Tunnel, the summit of the line would be reached, 361 feet above sea-level, at Montreuil-sur-Brèche. From that point the railway would pass through Hermes and Cauvigny, Persan, and cross the River Oise on a viaduct at Beaumont-sur-Oise. The 10 miles from Maffliers to St. Denis would pass Ecouen and bring the railway to the entrance of the Paris terminus, which would be in the Rue St. Lazare.

The scheme is not limited to the provision of a non-stop train service between London and Paris, but includes the inauguration of an elaborate system of non-stop electric suburban services, both from London and from Paris and of separate services to the coast. It is proposed to lay down four lines from London to

the entrance of the Channel Tunnel of which two only will pass through the Tunnel, and in addition, two extra lines for the suburban district, from London to Farningham. The inner pair of rails will be principally devoted to the Continental traffic; the next to the English stations beyond Farningham; and the outer lines to the London suburban traffic.

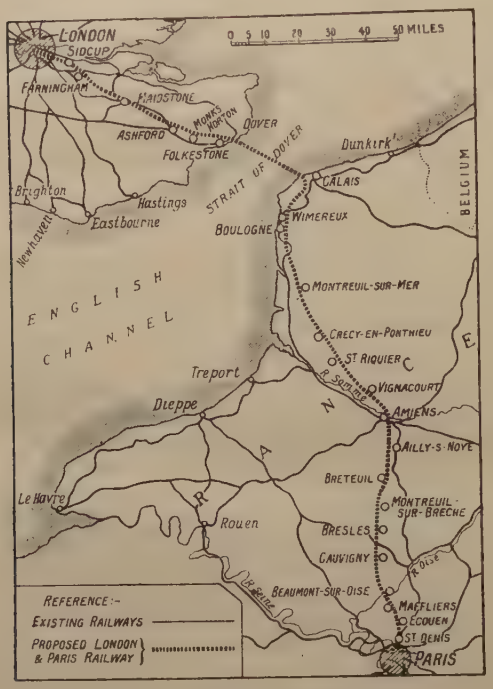

Fig. 1. — Map showing location of proposed railway.

In France it is similarly proposed to operate four lines from Paris to the entrance of the Channel Tunnel, and two additional lines from Paris to Beaumont-Persan for the suburban district. The limestone formations extend for 35 miles from Paris, and the total length of line to be operated from the Paris terminus is over 150 miles, more than double the length of the English railway. It is, therefore, thought that it will be a wise and prudent policy, contributing to efficient and economical working, to lay down six pairs of rails from Paris to Beaumont-Persan.

Gauge.

It is proposed to adopt Brunel's broad gauge of 7 feet throughout for the new railway, which will have no connections or branches. It is claimed that the broad gauge will reduce by more than 25 % the deadweight for the whole of the heavy passenger traffic, and will save the haulage of mililons of tons of unnecessary deadload every year, resulting in a large financial saving.

The average load of merchandise hauled in Great Britain in 1927 was 2.96 tons, weight of wagon about 7 tons, carrying capacity 10.28 tons. If the proposed railway hauls standard-gauge wagons thus loaded from England to the Continent, the tare weight will be 236 % of the paying load. If, on the other hand, broad-gauge wagons weighing 20 tons are loaded with 75 % of their maximum load of 50 tons, the percentage of tare is reduced to 53 %, or, if fully loaded, to 40 %. In the first case, only 30 % of the total load is hauled for payment; 70 % earns nothing at all. In the second example, 65 % pays, and 35 % is carried free; and in the third, 71 % pays, and only 29 % is free-hauled.

The broad gauge will permit the employment of 1 500-H.P. motors as against a maximum of 750 H.P. on the standard gauge.

Traffic.

Careful examination of the passenger and goods traffic between London and Paris satisfies accountants that the revenue would, in the course of a few years, at least double that of the present cross-Channel traffic receipts, and at even this moderate estimate, the initial outlay in construction would be justified and profitable. It is estimated that 12½ million people at present travel between London

and the Continent, two-thirds travelling to or from Paris and beyond.

Te scheme provides for 22 trains each way daily, with a 45 minutes' service, and an average of 608 passengers. Allowing for extra summer traffic, an accommodation of 10 700 800 seats would be provided for an estimated annual traffic of 8 333 333 passengers.

In addition, the scheme contemplates 12 similar trains being run each way between London and Boulogne daily, providing 5 836 800 seats annually. Capital expenditure is estimated at £189 177 094, including £ 30 811 200 for the tunnel. With gross receipts of over £35 000 000, a figure which is based on an average of £2 for a single fare from London to Paris, it is estimated that the working would yield an annual profit of over £12 000 000, enabling payment of 7 % on ordinary stock.

The question of the effect of the railway upon the Southern Railway of England and the Northern of France is dealt with in the book, where it is suggested that various offsets will be provided for lost traffic on either system. It should, it is thought, bring a large increase of foreign visitors to the southern resorts of England. The book also deals at length with the naval and military aspects of the Tunnel scheme, and it is suggested that if opposition on these grounds can be overcome, there would probably be no difficulty in regard to the financing of the scheme. There is no reference to competition with air traffic.

It is estimated that the construction of the railway and tunnel could be completed by modern engineering methods in six years, and that it would give employment, directly and indirectly, to at least 50 000 men in this country.

Appended to the book are : « a brief report from the consulting engineer, Mr. Theodore Stevens, M. Inst. C.E., the 1907 report by Sir Douglas Fox & Partners to the Channel Tunnel Company, estimates for rolling-stock for the English and French sections of the railway, for the Channel Tunnel, and summary, and detailed draft time-tables for the proposed high-speed shuttle service. There is also a map, of which we reproduce the salient portion.

It is understood that copies of the work have been sent to the Prime Minister as President of the Committee of Imperial Defence, and to others directly concerned. London & Paris Promoters Limited was registered as a private company on 3 December 1928 with a nominal capital of £100 in £1 shares to promote the scheme.

MISCELLANEOUS INFORMATION

[621 .132.8 (.41)]

1. — New Clayton steam rail cars for Ireland.

Figs. 1 and 2, p. 317.

(*The Railway Gazette.*)

In order to amplify existing passenger train services by providing more frequent facilities on certain sections where the traffic is comparatively light, the Great Southern Railways of Ireland have recently ordered a series of six Clayton patent steam rail coaches, and by the courtesy of the builders, Clayton Wagons Limited, of Abbey Works, Lincoln, we are enabled to describe and illustrate these new coaches herewith. Each of these coaches is provided with separate first and third-class compartments and a luggage compartment. In four of the coaches the third-class compartments seat 55 passengers, the first-class compartment nine passengers, and the luggage compartments each have a floor area of 45 square feet. In two of the coaches the third-class compartments seat 51 passengers, the first- class compartment five passengers, and the luggage compartments each have a floor area of 90 square feet.

The leading dimensions applicable to the whole of this series of cars are as follow :

Gauge	5 ft. 3 in.
Engine bogie wheels, diameter.	3 ft. 6 in.
— — wheelbase	7 feet.
Trailing bogie wheels, diameter.	3 ft. 1 $\frac{5}{8}$ in.
— — wheelbase	7 feet.
Bogies, centre to centre	42 ft. 6 in.
Length over buffers	59 ft. 6 $\frac{3}{4}$ in.
Width overall.	9 ft. 6 in.

The interiors of the third-class compartments are finished in varnished teak, and the first-class compartments in polished mahogany. The ceilings are painted white, and the floors are covered with brown cork linoleum. The third-class seats are upholstered in black and red repp, and the first-class seats are upholstered in tapestry. The luggage compartment is painted buff colour, the floor being covered with hardwood wearing strips, and tip-up seats upholstered in repp are provided to accommodate any passengers for whom seats cannot be found in the passenger compartments.

The body frame and underframe are designed structurally as a unit, and the body frame assists the underframe in withstanding stresses. The frames are constructed of rolled-steel members and the body-sides and roof are sheeted with Lysaght's C. R. C. A. steel panels. The body is mounted at each end on a swinging bolster, and double-coil helical bolster springs are used.

Engine and boiler.

The Clayton engine has two double-acting cylinders each 7 inches in diameter with a stroke of 10 inches. The steam distribution is effected by piston valves which are operated by eccentrics mounted on a layshaft. The eccentrics work in the crank-case oil bath. A simple device is used to control the angle of advance and throw of the eccentrics, so that a full range of cut-off from zero to maximum is under the control of the driver. By the same means the eccentrics are brought into the reverse position. The engine is balanced by means of weights secured to the crank-webs. The crankshaft has a roller bearing at the driving pinion end and a self-aligning ball bearing at the opposite end. All the working

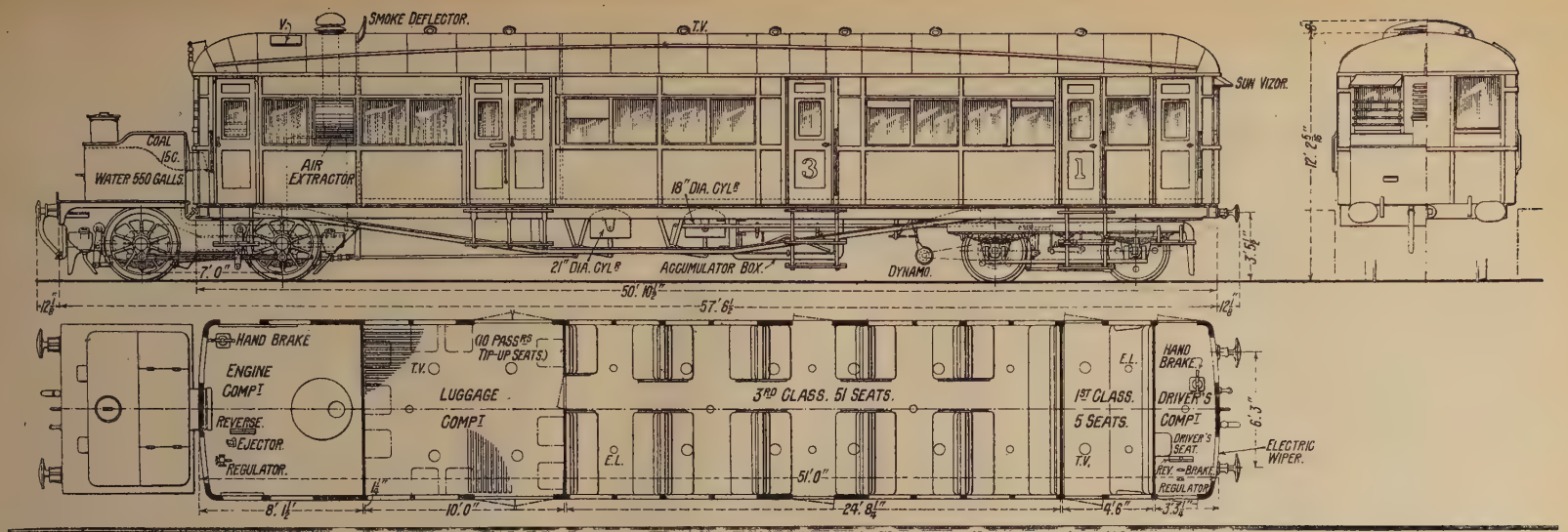

Fig. 1. — Side and end elevation and plan drawings of Clayton rail car seating 56 passengers.

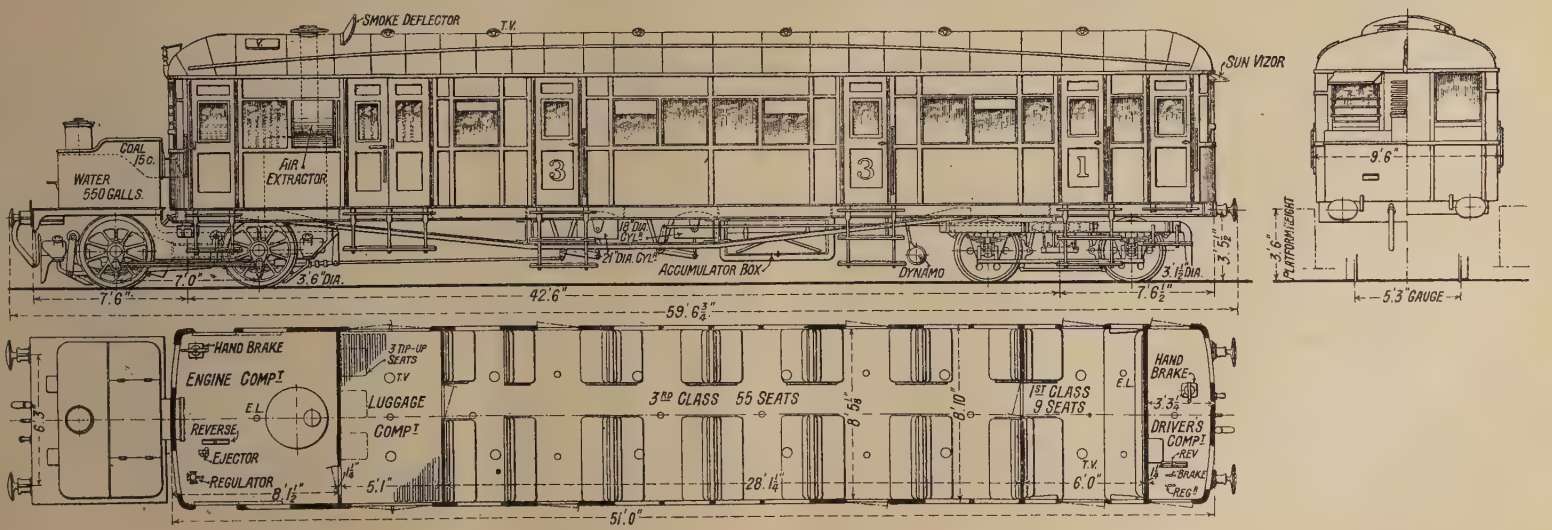

Fig. 2. — Side and end elevation and plan drawings of Clayton rail car seating 64 passengers.

Figs. 1 and 2. — New Cleyton steam rail cars, Great Southern Railways of Ireland.

parts of the engine are totally enclosed. The cylinders are lubricated by a « Eureka » lubricator, fitted in the driver's cab. The crankshaft revolutions of from 150 to 450 per minute are equivalent to car speeds of 15 to 45 miles per hour respectively.

The boiler is of the Clayton vertical type with water tubes and superheating coil, and supplies steam to the engine at a pressure of 300 lb. per square inch. It will evaporate 1 800 lb. of water per hour continuously. Firing is effected from the top through a stoking chute, and the furnace with tubes can be dropped for examination or for cleaning, by removing the nuts on the foundation rings. The boiler is fed by a steam-driven pump and an injector, and a feed-water heater is provided in the exhaust-pipe line. Transmission is by gearing from the engine crankshaft to the driving axle. The gears run in an oil bath and are totally enclosed.

Engine bogie.

The water tank and coal bunker are mounted on the engine bogie. The car may thus be watered and coaled by the standard appliances. The engine bogie is readily removable for repair if required, and a special arrangement of bolster is used at the engine end of the car so as to leave the engine fully accessible. The trailing bogie follows the accepted practice in British carriage design, and is of light but robust construction.

Controls are arranged at each end of the car so that it may be driven in either direction with equal facility. A snifting valve is fitted under the regulator to permit free coasting, and a speaking tube is arranged so that the driver may communicate with the fireman when the car is running with the engine bogie in the rear.

The car is fitted with the automatic vacuum brake and hand brake, Westinghouse steam-heating apparatus, and Stone's system of electric lighting with a dynamo driven off one of the axles of the trailing bogie. Side buffers, draw-hooks, and screw couplings are provided to enable the car to couple with the standard rolling-stock. The general design of the coach-work of these cars conforms with the modern tendency towards the employment of flush surfaces and the abolition of heavy mouldings in interior finish. Snapheaded rivets are used on the roof, and the riveting on the body sides is countersunk on the outside to preserve a flush finish. The roof of the car is painted white, and the sides and ends are finished in the Great Southern Railways' standard lake, with lining, numbering, and coat-of-arms in accordance with the railway company's standard practice.

[621 .135. (01]

2. — Modern counterbalance conditions,

By H. A. F. CAMPBELL.

(*Railway Age.*)

The underlying of fundamental principles of counterbalancing which have proved satisfactory on the smaller and lighter locomotives of the past, remain the same for the present day larger and heavier locomotive. The underlying laws do not change.

But some modern locomotives are balanced so poorly and disobey the fundamental rules so much that one of two things must be true. Either we have been all wrong in the past, or some of our modern locomotives sooner or later will increase the upkeep of roadbed, rails and bridges so much that their speed will be limited very strictly, or they will be ruled off the track altogether.

Some engineers believe that the underlying rules of mechanics and physics cannot be disobeyed without paying a price and that, sooner or later, those that are so today glaringly disobeying the rules will decide that the price they are paying is too high. It may be fortunate if the price is not finally paid in tragedy.

The last set of counterbalance rules was

drawn up in 1915 by a committee of the American Railway Master Mechanics' Association, of which S. G. Thomson, then of the Philadelphia & Reading was chairman. They may be summarized as follows :

Keep the weight of the reciprocating parts on one side down to 1/160 of the total weight of the locomotive.

Then balance evenly among the driving wheels one-half of this weight of these reciprocating parts.

It is better if the reciprocating parts can be made light enough so as to weigh only 1/200 of the total weight of the locomotive.

It is not considered necessary to cross-balance the weight of either the revolving mass or the reciprocating mass that is placed in the wheels.

In considering wherein these rules must be followed or changed we will divide the counterbalancing question into three phases :

a) The balancing of the direct fore and aft action of the reciprocating parts, tending to jerk the engine forward and backward;

b) The balancing of the nosing action, or swinging moment, caused by the action of the reciprocating parts swaying the engine across the track;

c) The balancing of the purely revolving parts in the wheel.

Reciprocating weights.

A very determined effort must be made to keep the total weight of the reciprocating parts on one side of the locomotive down to 1/200 of the total weight of the locomotive. This will need, first, the correct choice of the type of piston head, piston rod, crosshead and main rod; second, the choice of the proper materials, and, third, the most skilful design of each part. As the locomotive has more of its weight on the trucks, it will be easier to keep the reciprocating parts down to the desirable weight ratio. For example, it will be easier to do this on a 4-6-4 type than on a 4-6-2 type; easier on a 2-8-4 type than on a 2-8-2 type.

Per cent of reciprocating parts to be counterbalanced for various locomotive types.

Type of locomotive.	Per cent.	Type of locomotive.	Per cent.
4-4-0	50	2-8-0	50
4-6-0	50	2-8-2	40
4-4-2	40	2-8-4	30
4-6-2	40	2-10-0	50
4-6-4	30	2-10-2	40
4-8-2	30	2-10-4	30
4-8-4	30	4-12-2	30

It must be remembered that two improvements in the balancing effects can be obtained by choosing a somewhat higher working pressure, which means a smaller diameter of piston. The reciprocating weight will be reduced and the nosing couple or swaying moment can be reduced, because the cylinder centers can be brought in.

When the reciprocating parts have been kept down to 1/200 of the weight of the locomotive and kept in as close as possible to the center of the engine, then balance them to the extent shown in the table.

The percentages in the table take account of the variations in the amount of weight carried on the trucks.

Wherever it can be done, divide the reciprocating weight that is to be balanced evenly in all the driving wheels, and place this reciprocating weight directly opposite the crank pin.

Revolving weights.

It is in the balancing of revolving weights that some of the modern locomotives are getting away from the elementary principles of good balancing. It seems incredible to believe, but some of our present freight locomotives are out of balance on the main wheel from 1 200 lb. to 1 800 lb. Imagine what the effect must be on the machinery and the rail of having an unbalanced weight of 1 800 lb. revolving around at crank pin distance from the center of the axle at a rate of from 100 to 250 revolutions per minute. It would seem that we

are losing our sense of proportion when we try to operate such a piece of machinery, even granting that the rails and roadbed have been made heavier. It must aslo be borne in mind that, in addition to being out of rotative balance by this great amount, the wheel is still further out of balance by reason of the difference of plane in which these masses are revolving.

What can be done ? Insofar as the two-cylinder locomotive of high power capacity is concerned, very little can be done with the main wheel. A good answer would be to use a three-cylinder compound or a four-cylinder simple, duplex locomotive. But, if we are considering a two-cylinder locomotive, the revolving weights of the main wheel should go to the very limit to get out every extra pound of weight. It is surprising just how many pounds can be taken out, if a very determined effort is made to do so. With the larger diameter of drivers which make it possible, always cross-balance for the difference of the plane of these revolving weights. This much can and always should be done.

One interesting point should be noted with respect to three-cylinder locomotives. It is not necessary to balance any of the reciprocating parts. This leaves only the revolving weights to consider. With a fair-size driving wheel, these revolving weights can be balanced exactly. In other words, with a three-cylinder locomotive at all speeds, we only have the static load on the rail. This is well worth remembering when we consider that it is necessary to run the main wheel of the equivalent two-cylinder locomotive 300 lb. to 800 lb. out of balance, even when every possible care and skill has been taken.

[625 .233 (.42)]

3. — The Vickers " V. 1 " single battery train lighting system.

Figs. 3 and 4, pp. 321 and 322.

(*The Railway Gazette.*)

Although the well-known « slipping belt » system provided a solution to the problem of generating current for train lighting from a railway carriage axle, notwithstanding that rotation necessarily varies in speed within a wide range as well as in direction, it has been recognised for many years that electrical regulation is not only desirable, but is essential if electrical efficiency is to be secured. Hence, while the slipping belt has deservedly had a very wide vogue in all parts of the world, engineers have at the same time been working steadily in developing electrical regulation systems. Indeed, for a considerable time, such systems have been successfully used to a substantial extent, notably in the case of the Vickers Single Battery System, supplied by Vickers Limited, of Vickers House, Broadway, Westminster, London, S.W.1, which is extensively used on all railways, both at home and abroad including French and other Continental lines.

While, however, this system has given general satisfaction for a number of years past, certain possibilities of improvement necessarily manifested themselves, with the result that what is known as the « V.1 » system is now being applied, and it is this system with which this article is concerned.

The main feature is that the dynamo regulator is made to cover also the purpose formerly carried out by the lamp regulator, while at the same time the charging of the battery is so regulated as to enable it to operate under the most favourable conditions. The system, therefore, provides for charging in such a manner that the dynamo voltage is kept at that appropriate for the lamps while they are in use, but is at the same time raised to give the full battery charge when required. Further, the equipment is free from complication, requires no attention after being installed, involves practically negligible replacements in that there are hardly any parts which can call for renewal, automatically adjusts itself to widely varying conditions, and acts not only as a protector for the battery and the lamps, but also eliminates any possibility of excessive load being applied to the generator.

The main feature is that the operating coil

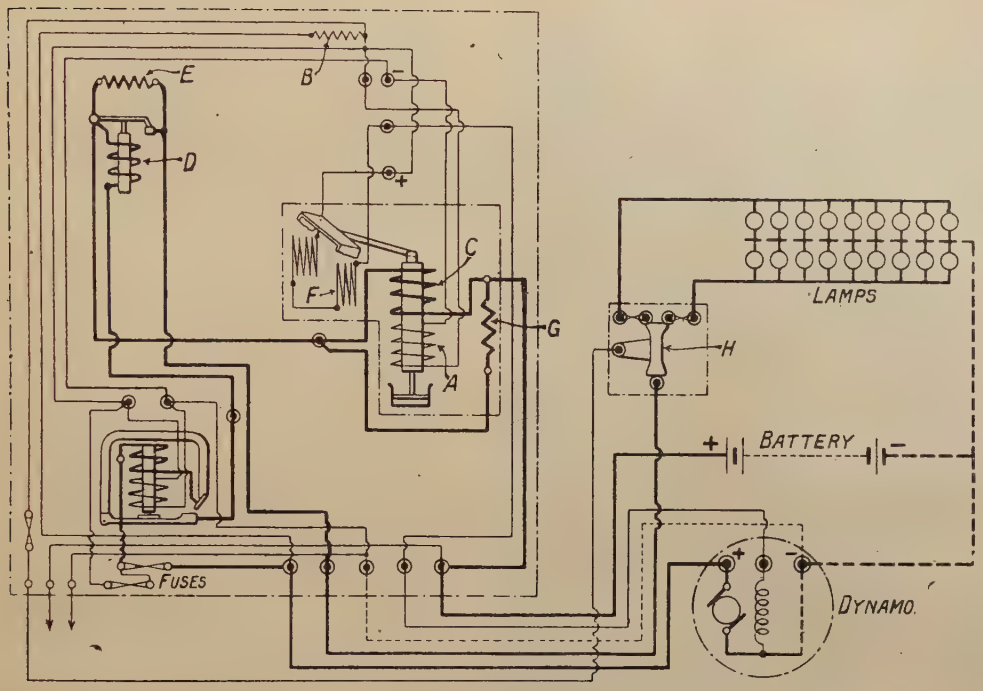

Fig. 3. — Diagram of Vickers' train-lighting system as fitted with « V. 1 » regulator.

of the dynamo regulator in connected across the lamp circuit so that the voltage delivered at the lamp terminals is maintained at the correct value. Between the positive terminals of the dynamo and the lamp circuit, however, a resistance is interposed, with the result that the dynamo voltage necessarily exceeds that received by the lamps by the product of the value of this resistance and the lamp current. The battery is connected to the dynamo side of this resistance, and consequently receives a voltage exceeding that of the lamps by an amount depending on the number of lamps in use. It thus receives a charge roughly proportionate to the lighting demand. This resistance is known as the « bucking » resistance.

It is not necessary for the battery always to be charged at a voltage corresponding to 2-66 volts per cell, so long as an occasional charge up to that value is given. It is, therefore, found sufficient to proportion the resistance so as to give a charging voltage of 2-4 — 2-5 volts per cell when full lights are « on ». This enables a smaller generator to be employed than would be necessary if a charging voltage of 2.66 volts per cell were given with full lights « on ». The regulator is, however, set to give 2-66 volts per cell when no lights are in use.

A regulator thus constructed gives the following results :

1. It is impossible for the battery to be overcharged. Hence, one fruitful cause of loss of active material, with consequent shortened life and increased maintenance cost, is removed, and that without the provision of any special apparatus requiring attention.

2. It is almost equally impossible for the cells to be undercharged so long as the equipment is in service, since any lowering of the state of charge of the battery is at once met by an increase in the charging current.

3. The reduction of charge as the battery approaches the fully charged condition, is very beneficial in preventing boiling away of electrolyte and loss of active material from the

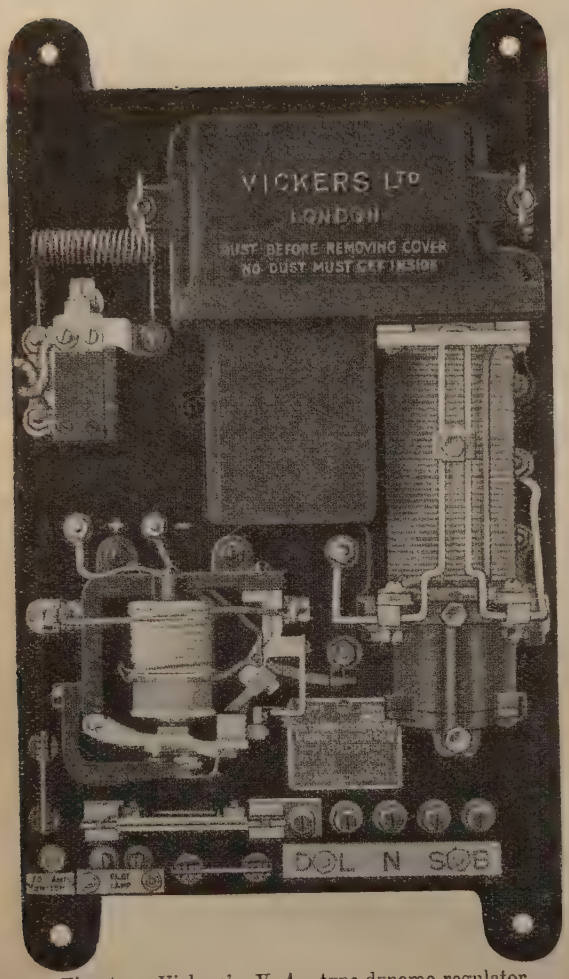

Fig. 4. — Vickers' « V. 1 » type dynamo regulator.

plates, with consequent deposit at the bottom of the cells.

4. In the case of a battery being accidentally discharged and allowed to stand, with consequent sulphation, it is found that this system gives a small charging current until the sulphation is broken down, followed by full charging current as the cell comes back to normal uncharged condition, which gradually tapers off again as they become fully charged. This is, of course, the ideal treatment under such conditions.

It is found that in practice the following settings for a 24-volt equipment give the best results :

Open circuit voltage « lights on » (lamp switch « on », but lamps disconnected elsewhere or removed from their sockets, and battery disconnected) 25-5—26.

Open circuit voltage « lights off » (lamp switch « off », battery disconnected), 32—33.

Voltage drop through battery resistance with full lamp current passing 3—3-5 volts.

The system gives, under the conditions noted, a practically constant lamp voltage varying very little from the standard 24 (within 4 % under practically all conditions and frequently closer), while, at the same time, it is impossible to over charge the battery, and practically impossible to undercharge it under any service conditions likely to be encountered. Furthermore, should the battery circuit be interrupted, no ill effect is caused, the lamp and dynamo voltage being controlled.

It should be noted that the function of the « battery resistance » above mentioned differs from that of the « lamp resistance » frequently encountered in train lighting systems, in that the latter is employed to lower the battery charging voltage to the lamp voltage, while in the present case the resistance serves to raise the lamp voltage to that necessary to charge the battery, and is thus termed a « bucking resistance ».

A view is reproduced showing a « V.1 » dynamo and lamp regulator, while the system as a whole may be considered in connection with the diagram also given.

A is the voltage coil of the operating solenoid of the regulator.

B is the resistance inserted in series with this coil when the lights are not in use.

C shows the charge-limiting series turns on the operating solenoid. D is the automatic short-circuiting switch which cuts the bucking resistance E out of circuit when the dynamo is not generating more current than is required by the lamps.

F is the field resistance in the regulator.

G is an adjustable shunt, whereby the proportion of the charging current, which passes through the series turns of the solenoid, may be varied if required.

H is the main lamp switch, provided with

means for short-circuiting resistance B when the lights are in use.

Experience has shown that this system thus meets practically every service condition, and will, indeed, satisfy every operating situation which can arise, including the most unexpected and sudden imposition of full or nearly full light load, the widest ranges of axle speed, long periods of standing or slow travelling speed, rapid sequences of change-over from battery to dynamo lighting due to speed variations below and over the change-over speed, and under circumstances which would normally be anticipated to be adverse from, if not definitely destructive of, battery efficiency.

Apart from the special regulating device, the equipment is practically the ordinary Vickers system which has given widespread satisfaction for a number of years past, and comprises dynamo suspended under the carriage and belt-driven so as to be drawn on its slings by about 30 degrees out of the vertical; a brush-rocking arrangement which maintains the polarity of the external circuits covering also change of the direction of rotation; and the dynamo regulator which controls the charging current to the battery, varies the dynamo output according to lamp load, and performs other necessary functions, this part of the apparatus being developed as above described to combine the functions of the lamp regulator. The battery equipment is, of course, that usually necessary (except that it can be left without supervision for long periods owing to the better regulation and absence of destructive action secured), as also the main switches and other details.

NEW BOOKS AND PUBLICATIONS

[385]

SHERRINGTON (C. E. R.), M. C., M. A. (Cantab.), A. M., Inst. T. — **The Economics of Rail Transport in Great Britain.** — 2 volumes in 8° (5 1/4×8 1/2 inches) with tables & figures in the text. Vol. I : History and development, 283 pages. Vol. II : Rates and service, 332 pages. — London, Edward Arnold & Co. (Price : 12 sh. 6 d. net per volume, obtainable separately.)

In the compilation of this survey of British Railways, Mr. C. E. R. Sherrington has had the advantage of a wide and varied academic experience. Before taking up his present appointment in London, he spent two years in the study of economics at Cornell University, New York; and he is well known in railway circles in London not only as a lecturer on transport at the London School of Economics (London University), but also as Secretary of the Railway Research Service, which is maintained by the British Railway Companies for the purpose of investigating railway questions in this and other countries. M. Sherrington is, therefore, particularly well equipped for the task of preparing a treatise of this nature.

The book is produced in two volumes. The first volume, which bears the subtitle « History and Development », opens with a chapter dealing in broad outline with the function of transportation and describing generally the scope of the complete work. The next five chapters are historical, and trace the growth of the British Railways from their early beginnings to the Amalgamated Groups of the present day. The author then goes on to discuss the development of the permanent way and of the steam locomotive, and carriage and wagon design. The volume concludes with two chapters on the subject of Government regulation, which are especially valuable for their summarised description of the principal features of the railways Act, 1921. An appendix is added setting out the constituent and subsidiary companies of the four groups.

In the second volume — « Rates and Service » — the author examines, with careful analysis and keen insight, the principal structure and the organisation of the railways and the methods of charging for services rendered. He opens with a chapter on the economic function of rail transport, in the course of which he emphasises the value, from the point of view of industrial prosperity, of cheap transport. The question of organisation is next dealt with, and examples are given of departmental and divisional organisations. A chapter follows on railway finance, in which the characteristics of railway capital are discussed, and questions of revenue and expenditure are considered with particular reference to the difficulty of dividing expenditure as between passenger and freight traffic. The relationship between the Railways and the traders are then dealt with, and a brief chapter is devoted to the origin and the functions of the Railway Clearing House.

In the succeeding chapters, which are devoted to an examination of rates and fares, of passenger and freight train operation, and of traffic control, the author is at his best. He handles these subjects with directness, and marshalls his facts and presents his arguments with admirable clarity. The remaining chapters of the book touch on railway electrification,

statistics, the problem created in recent years by road competition, and finally on the much debated question of State ownership. He concludes with the dictum that « national and railway prosperity are interdependent and reactionary upon each other and an enlightened policy of minimum legislation and regulation by the State should be the corollary of a maximum amount of efficiency and economy by the railways ».

No reader of Mr. Sherrington's work can fail to be struck by the amount of industrious research which its preparation must have entailed, and by the author's ability to collate facts and present them interestingly and in logical sequence. He handles railway problems as he finds them, basing his arguments on generally accepted facts and opinions, and refrains, for the most part, from venturing to prophesy about future railway development. Altogether this book is a valuable addition to contemporary railway literature.

A useful bibliography is added for reference at the end of each chapter.

[385 .65 (.4)]

CENTRAL OFFICE FOR INTERNATIONAL RAILWAY TRAFFIC, at Berne. — **List of the subjects given in Appendix I of the International Convention dealing with the transport of goods by railway, dated the 23 October 1924 (C. I. M.) in the form of tables with alphabetical contents list. In force as from the 1 October 1928.** — A pamphlet large octavo, of VII + 76 pages, with illustrations. — 1928, Berne, 36, rue Monbijou, Office central des transports internationaux par chemins de fer. — (Price : 3 Swiss francs.)

Appendix I. of the C. I. M. (International Convention-Goods) contains not only the special regulations applying to the carriage of goods, which in principle, ought not to be accepted for conveyance by rail, but also the regulations to be observed in the event of the despatch of objects which are only accepted for conveyance under specified conditions. In the text of Appendix I which contains many references and recapitulations, these exceptional requirements and special arrangements follow immediately after the enumeration of the different articles in question. This arrangement of the text is not always helpful to the railway staff and to the senders when having to draw up quickly a list of the requirements applying to the carriage of a given material. In consequence, the countries signing the C. I. M. acting through the Commission of Experts provided for in article 60, paragraph 2, of the Convention, have requested the Central Office at Berne to prepare a list of the articles enumerated in Appendix I in the form of tables with an alphabetical contents list.

The list, in the form of tables, shews the materials in conformity with the text of Appendix I; the conditions of carriage have been arranged in the order of the operations to be completed when each article is handed in for conveyance.

The alphabetical contents list at the end of the pamphlet contains the complete list of all the articles enumerated in Appendix I and shews, for each article, the class or the group and the page of the tables giving the conditions of conveyance.

The senders and the railway employees can thereby easily find in the alphabetical contents list the article to be despatched, as well as the pages of the tables giving the regulations to be followed.

This pamphlet forms a useful working instrument for railway employees and consignees, especially warehousemen and manufacturers having to arrange the carriage of dangerous or noxious goods. It is published in French and in German in separate editions.

ERRATUM.

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On page 1014 : « Gefle Dala Railway », *should be read :* « Göteborg-Dalarne-Gäfle Railway.